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INVESTIGATION INTO THE CARRYING ABILITY OF PEDICLED BONE GRAFTS DURING TRANSPLANTATION

By

SANDOR MEDGYESI

Received 1? xi 66

It is well known that pedicled grafts are vulnerable and in order to preserve the blood supply it is necessary to handle them by an atraumatic technique. Their transport from the donor site must take place without too much strain upon the pedicle. However, it is not always possible to avoid a certain torsion, flexion or extension of the pedicle when placing it on the recipient site. In dealing with tubed pedicles, rotation flaps and other types of skin flaps, however, there can be ample inspection of the graft, so that measures may be taken in time. On the other hand, the pedicled bone grafts cannot of course be inspected. When a poor result manifests itself radiologically or clinically, several weeks or months may have passed.

Good results have previously been obtained by pedicled bone grafts under experimental conditions (3, 5). Under these conditions, however, care is taken not to strain the pedicle, as the sole object has been to ascertain whether these pedicled bone grafts do survive at all, and whether they preserve their osteogenetic activity and healing ability.

To find out what happens to the graft if the pedicle is placed into positions to which it would otherwise be exposed when placed in the recipient site, the following experiment was carried out.

METHOD

The experimental animals were adult rabbits. The grafts were removed from the greater trochanter on both sides, using the gluteus med. and part of the rotator muscles as pedicle. The grafts were wrapped in polyethylene foil to avoid ingrowth of blood vessels from the surroundings. The pedicles were exposed in a length of 1 cm. On the right side nothing further was done, as this side served as a control.

In 5 of the rabbits the pedicle on the left side was torquated 180° and fixed in this position. In the next 5 rabbits the grafts were pulled 1 cm distal to the donor site and fixed there. This procedure causes great tension on the pedicle—measured by a spring balance while pulling the graft from the donor site to the recipient site—corresponding to 2.1 g. In the last 5 cases the pedicle was flexed so that the sawn surface of the graft faced the side opposite to the original.

The rabbits were killed two weeks after the operation. The specimens were studied histologically after being stained with haematoxylin eosin. Two of each group of rabbits had microangiography by the method of Spalteholtz filling the abdominal aorta with Prussian blue.

In addition absorption experiments were done on 4 recently operated rabbits using radioactive sodium. 0.2 μC Na+ in 0.1 ml physiological saline was injected subperiosteally into the graft followed by counting with a Geiger-Muller counter. The rate of absorption was taken to represent the circulation in the pedicle. The *absorption rate for the normal trochanter was fixed in an experiment on two* trochanters.

RESULTS

The torsion was indubitably the most detrimental action. In three grafts all the original osteocytes perished. In two very slight survival could be traced. Nevertheless the osteogenetic activity in these grafts was surprisingly good (Figure 1). All the control grafts survived and showed relatively little new formed bone (Figure 2). Extension and flexion of the pedicle exerted a considerably less detrimental effect. Total necrosis of the graft was found in only one rabbit after extension and in one after flexion of the pedicle. On the average half the osteo



Figure 1. Complete necrosis of the graft. Pronounced subperiosteal callus formation. Torsion of pedicle 180°.



Figure 2 Graft with intact pedicle Bony tissue alive throughout The picture is taken in the vicinity of the sawn site



Figure 3 Graft with extended pedicle About half the original osteocytes are alive in this trabecule which is from the middle of the graft Some newformation of bone at the bottom

cytes survived in the remaining grafts—in three up to 75 per cent (Figure 3) However in this group too the control grafts showed better survival of the original cells

Microangiography in a few cases gave a result somewhat divergent from the histological findings the number of blood vessels that filled with Prussian blue being larger than might be expected according to

In 5 of the rabbits the pedicle on the left side was torquated 180 and fixed in this position In the next 5 rabbits the grafts were pulled 1 cm distal to the donor site and fixed there This procedure causes great tension on the pedicle—measured by a spring balance while pulling the graft from the donor site to the recipient site—corresponding to 2 kg In the last 5 cases the pedicle was flexed so that the sawn surface of the graft faced the side opposite to the original

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In addition absorption experiments were done on 4 recently operated rabbits using radioactive sodium 0 2 μC Na^{24} in 0 1 ml physiological saline was injected subperiosteally into the graft followed by counting with a Geiger Müller counter The rate of absorption was taken to represent the circulation in the pedicle The absorption rate for the normal trochanter was fixed in an experiment on two trochanters

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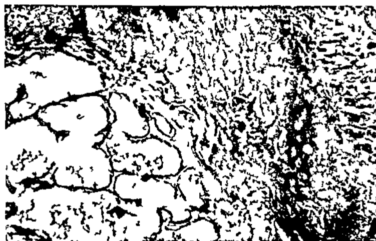


Figure 1 Complete necrosis of the graft Pronounced subperiosteal callus formation Torsion of pedicle 180

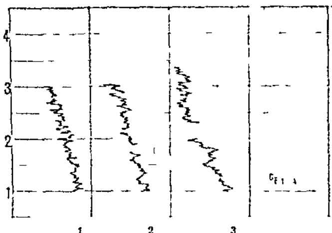


Figure 6 Absorption curves as traced by the Geiger Muller counter The curves start at the bottom The absorption was studied for 20 minutes 1 Normal trochanter 2 Pedicled graft 3 Pedicled graft before and after torsion

torsion caused an extreme reduction in the absorption Extension also entailed marked reduction while flexion in the studied case had no effect (Figure 6)

DISCUSSION

Strainful forced positions of the grafts were deliberately chosen mainly in order to ascertain the utmost carrying ability It is not surprising therefore that *e g* a torsion of 180 of a relatively short and thick pedicle entailed primary closure of most veins and arteries in it leading to total necrosis of the bone A somewhat unexpected finding was the pronounced new formation of bone around these grafts It is known however that an osteogenetic factor exists in connexion with a dead bone (1 7) This factor is released by the dying osteocytes and is presumably a protein (2 6) The mechanism of its effect has not been fully clarified It is believed that it takes place through stimulation of capillary proliferation (6) Under the present experimental conditions therefore the grafts have not lost their value as transplantation material in spite of the cell death because of the preserved osteogenetic ability The strong traction did not harm the graft as much as did torsion presumably because the blood vessels are not destroyed before the muscular tissue Incidentally the tense condition always decreases as time goes by because the tissue yields

A radioactive sodium clearance test was performed as is done in

connection with pedicled skin flaps (4) The test was illustrative and the results were on the whole in conformity with the histological findings The method is simple and appears to afford good orientation concerning the circulation in the pedicled grafts

SUMMARY

An experiment on rabbits is reported Pedicled bone grafts were removed from the trochanters the stalks were torquated extended and flexed to obtain an impression of their tolerance The histological and microangiographic investigations of the specimens were supplemented by absorption experiments using Na [24] The most detrimental process was the torsion which caused total necrosis of the bone The other two procedures did less to reduce the survival of the original cells The grafts preserved an osteogenetic activity in all cases

RESUME

Il est rapporte une experience a laquelle on a procede chez des lapins Des greffes osseuses pediculees ont ete retirées des trochanters Les pedoncules ont ensuite ete tordus etires et flechis pour avoir une impression de leur resistance Les examens histologiques et microangiographiques des specimens ont ete completes par des expériences d absorption en utilisant du Na [24] radioactif Le processus le plus prejudiciable a ete la torsion qui causa une nécrose totale de l os Les deux autres procedes ont moins contribue a reduire la survie des cellules originales Dans tous les cas les greffes ont conservé une activité osteogenetique

ZUSAMMENFASSUNG

Ein Versuch mit Kaninchen wird berichtet Gestielte Knochenspahne wurden von den Trochantern entfernt Die Stiele wurden torquiert gestreckt und gebeugt um einen Eindruck ihrer Widerstandskraft zu erhalten Die histologischen und mikroangiographischen Untersuchungen der Proben wurden mittels Absorbtionsexperimenten erganzt indem man radioaktives Na [24] verwendete Das schädlichste Vorgehen war die Torsion da sie vollstandige Nekrose des Knochens hervorrief Die beiden anderen Verfahren fuhrten in geringerem Grade zu einer Herabsetzung des Überlebens der ursprünglichen Zellen Die Spahne bewahrten in allen Fällen eine osteogenetische Aktivitet

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An experiment on rabbits is reported Pedicled bone grafts were removed from the trochanters the stalks were torquated extended and flexed to obtain an impression of their tolerance The histological and microangiographic investigations of the specimens were supplemented by absorption experiments using Na ⁴ The most detrimental process was the torsion which caused total necrosis of the bone The other two procedures did less to reduce the survival of the original cells The grafts preserved an osteogenetic activity in all cases

RESUME

Il est rapporte une experience a laquelle on a procede chez des lapins *Des greffes osseuses pediculées ont ete retirées des trochanters* Les pedoncules ont ensuite ete tordus etires et flechis pour avoir une impression de leur resistance Les examens histologiques et microangiographiques des specimens ont ete completes par des experiences d'absorption en utilisant du Na ⁴ radioactif Le processus le plus prejudiciable a ete la torsion qui causa une necrose totale de l os Les deux autres procedes ont moins contribue a reduire la survie des cellules originales Dans tous les cas les greffes ont conserve une activite osteogenetique

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ANALYSIS OF DIURNAL RATE OF LONGITUDINAL GROWTH OF BONES

By

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Received 3 iii 67

In an investigation of the effects of oxygen breathing on the growth in length from the epiphyseal growth plate with oxytetracycline labelling it proved necessary to ascertain whether such growth has any diurnal periodicity The possibility of such a rhythm has been suggested by Simmons Utilizing the colchicine method in growing mice he found the number of mitotic figures in the epiphyseal plates of the distal femur and proximal tibia to be 26 8 per cent respectively 23 3 per cent larger in a night group than in a day group (*Simmons* 1962) In an other study utilizing glycine C–14 incorporation (*Simmons* 1966) he established that collagen synthesis and new bone formation had a corresponding rhythm with the greatest activity in the environmental light period 09 00–21 00 although the rats feed most actively at night He does not say whether this implies a corresponding variation of the growth in length of the metaphysis or an increase in the height of the epiphyseal plate or simply a variation in the activity without any effect on the metric growth in length of the bone He felt that the day night differences reflected the diurnal variation of the secretory activity of the parathyroid gland and the adrenal cortex This diurnal periodicity is reflected by a wide variety of tissues and has also been demonstrated with tritium thymidine in growing bone (*Messier & Leblond* 1960) The purpose of the present study was to ascertain whether allowance must be made for any such variation in the longitudinal growth rate of the metaphysis of the bone in young rabbits as measured by oxytetracycline fluorescence labelling during short time variation of the oxygen content of the air inhaled

METHOD

The growth in length of the bone was measured by the technic of *Hansson* (1967). Oxytetracycline in a dose of 1 mg/kg bodyweight was injected i v into 4 to 6 weeks old rabbits Such doses do not influence the growth (*Hansson* 1967) Repeated injections at exactly 12 hour intervals mark the position of the zone of calcification on each occasion in sections placed parallel to the metaphyseal trabeculae these appear in the ultraviolet microscope as parallel lines spaced at intervals corresponding exactly to the growth in length of the metaph sis during each twelve hour period According to this method the proximal part of the tibia is dissected out fixed for two days in pure ethanol and sectioned with a razor blade without previous decalcification The sections are treated for five minutes in xylol and mounted in DePeX. The distance between the lines was measured in 5 to 10 sections from each animal and the means were calculated The error of the method in the hands of the author has been determined by simultaneous preparations of the left tibia and the right independently and the mean difference was 3 7 per cent (*Persson* 1967)

MATERIAL

The material consisted of 28 white rabbits aged 4–5 weeks from five litters The animals were kept together with their mothers in hutches in an in door stable and were given pellets and water *ad lib* The stable was illuminated by daylight from 5 a m to 7 p m Each animal received all together 5 injections of oxytetracycline the interval between consecutive injections b ing exactly 12 hours to allow 4 semi diurnal recordings in each animal The animals were divided into two groups two litters of totalling 13 animals we e given the injections at 13 40 hours and 01 40 hours respectively (in Table 1 called p m /a m) and 15 rabbits belonging to the remaining three litters were given injections at 07 40 and 19 40 hours (in Table 2 called day/night) The use of this 6 hour difference between the times of the injections in the two groups was intended to reveal any variation possibly concealed by being equally large before and after the time of the injection By judging from four semi diurnal observations in each animal it was possible to see if any variation found was repeated in both the conse utive days thereby giving support to a true diurnal rhythm

RESULTS AND DISCUSSION

The mean values show in Table 2 that the distance was about 1 per cent more during the daytime than at night and in Table 1 about 1 per cent greater in the afternoon than during the morning hours This tendency was noted in both days in both groups but the differences were too small to be statistically significant using the t test The values noted on the second day were also somewhat lower than those recorded on the first day which is the normal decrease at this age (*Hansson* 1967) Since the 12 hour periods in the two groups over lapped one another by 50 per cent it was possible also to evaluate the

Table 1 Growth distances in microns per each of four consecutive periods of 12 hours and mean values P m is 13 40–01 40 a m is 01 40–13 40

Rabbit No	p m	a m	p m	a m
1	230	210	230	220
2	250	250	260	250
3	220	230	230	230
4	260	240	240	240
5	260	260	250	250
6	270	250	260	240
7	230	240	230	230
8	300	310	300	300
9	260	260	260	240
10	290	290	290	290
11	290	280	300	290
12	290	280	280	290
13	300	310	300	300
Mean value	265	262	264	259

Table 2 Growth distances in microns per each of four consecutive periods of 12 hours and mean values Day is 07 40 19 40 night is 19 40–07 40

Rabbit No	Night	Day	Night	Day
14	280	280	280	290
15	220	240	190	200
16	280	270	290	300
17	270	280	260	270
18	270	270	260	280
19	260	260	260	270
20	270	270	280	270
21	270	280	260	250
22	300	310	300	290
23	260	260	250	260
24	290	280	290	250
25	300	300	300	300
26	300	300	300	290
27	300	320	300	300
28	300	300	300	300
Mean value	277	281	275	277

growth during 6 hour periods If these 6 hour periods be called a b c and d, with period a beginning at 01 40 hours the mean value of $b+c$ will be larger than that of $a+d$, and that of $c+d$ larger than that of $a+b$ Addition of these inequalities will show that $c>a$ that is growth

is greater during 13 40–19 40 than during 01 40–07 40 Normalisation of the means of the observations (a+b+c+d=1) will show finally that d>b i e growth is greater during 19 40–01 40 than during 07 40–13 40 But since the differences found were about 1 per cent only and statistically insignificant they warrant no final conclusions It would appear that the growth in length from the epiphyseal growth plate in young rabbits does not vary to any considerable extent from one 6-hour period to another unless diphasic variation occurs within periods of *less than 6 hours a possibility that seems unlikely Even if such a* short diphasic variation did occur it would in no way influence the value of this tetracycline method for studying growth during consecutive 12 hour periods

SUMMARY

A diurnal rhythm in the growth of bones has been reported by Simmons To see whether this rhythm is found in the metric growth in length of the metaphysis in rabbits oxytetracycline labelling was used *by repeated injections at 12 hour intervals The variation found was* statistically insignificant the mean differences being about 1 per cent with greater values for the afternoon Allowance for a diurnal rhythm is not necessary in the use of this method

RESUME

Un rythme diurne de la croissance des os a ete rapporte par Simmons Pour constater si ce rythme se trouve dans la croissance metrique en longueur *de la metaphyse chez les lapins on a utilise une coloration a* l oxytetracycline par injections repetees a 12 heures d intervalle La variation constatee est insignifiante statistiquement la difference essentielle etant d environ 1 per cent avec des donnees plus elevees dans l apres midi La reconnaissance d un rythme diurne n est pas necessaire si l on utilise cette methode

ZUSAMMENFASSUNG

Ein täglicher Rhythmus des Knochenwachstums ist von Simmons berichtet worden Um zu sehen ob dieser Rhythmus im metrischen Längenwachstum der Metaphyse von Kaninchen gefunden werden kann wurde Oxytetracyklinmarkierung mittels wiederholter Injektion in 12 stündlichen Intervallen verwendet Die gefundenen Verschiedenheiten

waren statistisch nicht bezeichnend indem die Hauptunterschiede ungefahr 1 prozent mit grosseren Werten am Nachmittag waren Berucksichtigung eines taglichen Rhythmus ist nicht notig bei der Anwendung dieser Methode

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MORPHOLOGICAL CHANGES IN STRIATED MUSCLE DURING ISCHAEMIA

A clinical and histological study in man

By

KAUKO A SOLONEN & LARS HJELT

Received 27 iv 67

Ischaemia is a prerequisite for modern surgery of the hand However ischaemia is an unphysiological condition which leads to anoxia of tissues and initiates changes of cellular death Opinion varies as to how long ischaemia can be maintained without endangering the tissues from 1 to 3 hours being the time usually suggested

Fishback & Fishback (1932) investigated muscle degeneration following ischaemia According to them the first change is slight granular clouding with dimming of cross striations of muscle This is followed first by oedema of fibres with prominent longitudinal fibrils and then by vacuolization granular albuminous and fatty degeneration and further waxy degeneration and disruption of the tissues *Harman* (1947) made an experimental study of muscle ischaemia in the rat and in the rabbit He observed increased cross striations while the longitudinal striations decreased and the muscle fibres were more clearly distinguishable from one another than usual as a result of ischaemia Prolonged ischaemia was followed by so called Bowman s discoid degeneration In their electron microscopical studies *Moore Ruska & Copenhaver* (1956) concluded that in post ischaemic degeneration of the muscles the extent of degeneration is not directly a function of time but depends on whether the muscle is stretched or not and on its content of mitochondria They saw severely damaged and almost normal fibres as early as 20 minutes and as late as 16 hours after the circulation had been restored *Dahlbäck & Rais* (1966) investigated the morphological changes in cross striated muscle of the rabbit after

ischaemia of varying duration and after post ischaemic periods of varying length On gross examination they found that oedema of the muscle was already visible after 30 minutes ischaemia These workers found that the degenerative changes became more marked with increasing duration of ischaemia and such changes were demonstrable after ischaemia of 30 min The changes were slight as long as the muscle was ischaemic but increased rapidly when the circulation was restored

Our aim was to elucidate by a histological method the changes occurring in human cross-striated muscle during ischaemia a search of the literature having failed to reveal any investigation on human material

MATERIAL AND METHOD

The material was obtained at operation on the hands of 17 patients aged 2 to 46 years These were reconstructive operations after injuries sustained in accidents which in the majority of cases required tendon reconstruction with the aid of free tendon grafts but in some cases also transposition of tendons

Exsanguination was achieved in the usual manner by raising the limb and applying Esmarch s bandage and ischaemia was maintained with a tourniquet The tourniquet pressure was 280 300 mm Hg In 13 cases the specimen was taken from the palmaris longus muscle in 3 from the superficial flexor digitorum muscle and in 1 from the extensor carpi ulnaris The muscle and its tendon were always entirely undamaged and functioning and there was no scar tissue The specimen was taken from the distal end of the muscle together with the transplant grasping the tendon the muscle was carefully lifted and severed with a sharp knife while the region of the specimen remained untouched by any instrument When the tendon had been divided from the specimen the latter was immediately fixed in a 4 per cent neutral formol Paraffin blocks were made in the usual way Sections from each specimen were stained with haematoxylin eosin van Gieson and Gomori s trichromic staining

At histological examination particular attention was paid to degenerative and reactive changes (Figures 1 2 3 4)

We did not consider quantitative measurement of the changes possible except by rough estimation The changes were thus classified as follows

0 no changes
1 slight changes
2 moderate changes
3 severe changes (cf *Dahlback et al*)

RESULTS

On gross inspection nothing abnormal e g no oedema was seen in the specimen

The histological findings have been compiled in Table 1

Table 1 Histological changes

Case number	Age in years	Period of ischaemia in minutes	Degeneration			Changes of muscle striation	Inflammatory cell reaction	Increase of sarcolemmal nuclei
			Granular	Vacuolar	Hyaline			
1	2	30	0	0	0	0	0	0
2	46	35	1	0	0	0	0	0
3	36	40	1	1	0	1	0	0
4	35	40	1	1	0	0	0	0
5	26	43	1	0	0	3	0	0
6	37	45	2	1	0	1	0	0
7	39	50	1	1	0	1	0	1
8	10	50	1	1	0	2	0	0
9	16	50	1	0	0	1	0	0
10	38	55	1	1	0	1	1	1
11	33	60	1	1	0	1	1	1
12	25	65	2	1	0	2	1	1
13	25	74	2	1	0	2	1	2
14	18	75	1	1	1	3	0	1
15	18	80	1	1	0	2	1	2
16	27	90	2	2	1	3	2	2
17	40	135	2	2	0	3	1	3

DISCUSSION AND CONCLUSIONS

No macroscopic changes were visible in the specimens taken during ischaemia

After a short period of ischaemia degeneration is at most slight Granular degeneration was noticed in all except case no 1 with ischaemia of only 30 minutes The degree of degeneration varied and it had a tendency to increase with the period of ischaemia Vacuolization and hyalinization did not appear before 40 minutes ischaemia After ischaemia of 1 hour or more signs of degeneration became numerous even before the circulation was restored

The inflammatory cell reaction was seen first after 55 minutes ischaemia It was always slight but clearly increased with longer periods of ischaemia

No haemorrhages were seen Slight erythrocyte extravasation might have been the result of pressure by Esmarch s bandage In ischaemia of more than 1 hour an observation pointing to oedema was separation of the muscle fibers and an increased space between the fibrils while

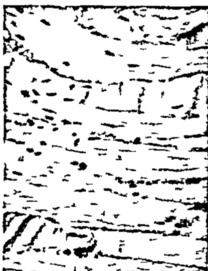


Figure 1 (Case 10)—Muscle specimen after 55 minutes ischaemia Variation of striation and early degenerative changes × 120 Photographed in polarized light

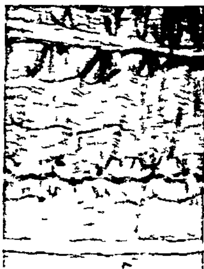


Figure 2 (Case 13)—Muscle specimen after 74 minutes ischaemia Variation of striation and degeneration × 120 Photographed in polarized light

cross striation simultaneously increased These changes were also a function of time

The amount of sarcolemmal nuclei increased with increasing duration of the ischaemia

We may conclude that capillary and cell damage caused by ischaemia become histologically demonstrable after ischaemia of more than 30 minutes duration The changes are mild however until about 2 hours after the onset of ischaemia It should be mentioned that in none of the patients were there any postoperative signs indicative of irreversibility of the changes occuring during or after ischaemia

The aggravation of the changes occurring after restoration of the circulation which according to earlier reports and clinical observations (hyperaemia oedema) seem probable could not be investigated in this connexion



Figure 3 (A B) (Case 17)—Severe degenerative changes in striated muscle after 135 minutes ischaemia Note loss of striation and increase of nuclei × 120

SUMMARY

A study was made of the histological changes visible in muscle specimens taken from 17 patients undergoing surgery of the hand after tourniquet ischaemia of varying duration

It appeared that degenerative changes of the muscular tissue oedema and the inflammatory cell reaction as well as the number of nuclei increased with prolonged ischaemia

The changes were slight at first but increased when the ischaemia

had been maintained for about 35 minutes and became more marked with time

Postischaemic changes were not investigated

RESUME

Il a ete procede a une etude des alterations histologiques visibles dans des specimeens de muscles preleves chez 17 malades ayant subi une intervention chirurgicale dans la main apres ischemie au tourniquet de duree variable

Il est apparu que les altérations degeneratives du tissu musculaire l oedeme et la reaction inflammatoire des cellules de meme que le nombre des noyaux augmentent loorsque l ischemie est prolonges

Les altérations etaient legeres au debut mais augmentent lorsque l ischemie est maintenue pendant environ 45 minutes devenant plus marquees avec le temps

Il n a pas ete fait de recherches sur les alterations post ischemiques

ZUSAMMENFASSUNG

Eine Studie der histologischen Veranderungen in Muskelproben wurde an 17 Patienten vorgenommen die wahrend handchirurgischen Operationen Blutleere verschiedener Dauer unterworfen waren

Es zeigte sich dass die degenerativen Veranderungen des Muskelgewebes Ödem und entzundliche Zellreaktion und auch die Zahl der Zellkerne mit der Verlangerung der Blutleere zunahmen

Die Veranderungen waren im Beginn nur leicht nahmen aber zu wenn die Blutleere fur ungefahr 45 Minuten aufrechterhalten wurde und wurden mit der Zeit mehr ausgesprochen

Postischaemiche Veranderungen wurden nicht untersucht

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METABOLIC CHANGES IN THE UPPER LIMB DURING TOURNIQUET ISCHAEMIA

A Clinical Study

By

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Received 29 iv 67

A bloodless field is essential in surgery of the upper limb But there are risks involved in maintaining it the greatest of which is probably ischaemia of unduly long duration Some workers attribute so called tourniquet paralysis to ischaemia (*Bentley & Schlapp* 1943 *Dery Pelletier, Jacques, Clavet & Houde* 1965) All tissues doubtless suffer from ischaemia which actually represents the beginning of tissue death *Negovski* (1962) established a metabolic condition similar to that occurring in an ischaemic limb in the blood of patients in terminal states or during clinical death The tissue changes are best studied in histologic specimens but it is only exceptionally possibly to obtain such material *in vivo* without harm to the patient Capillary blood is in metabolic equilibrium with the tissue in question especially when the blood flow is stopped In such circumstances blood taken from a vein behind the capillary bed obviously possesses the same properties as capillary blood This being the case it is possible to elucidate metabolic phenomena of the tissues by means of certain haematologic studies The purpose of the present work was to study the metabolic changes demonstrable in the blood after varying periods of ischaemia in connection with operations on the upper limb

MATERIAL AND METHOD

The series comprised 20 patients aged 13-58 mean age 28 5 years A reconstructive operation of the hand of varying duration was performed on all the patients The duration of *ischaemia* was 35 155 min mean 99 min

A common note

In the tables the solid line represents the average values for the limb kept in ischaemia the dotted line the average values for the intact limb The vertical lines show the deviation of determinations The black spot on the left indicates the average of determinations before the beginning of anaesthesia

Table 1 pH determinations after opening the tourniquet

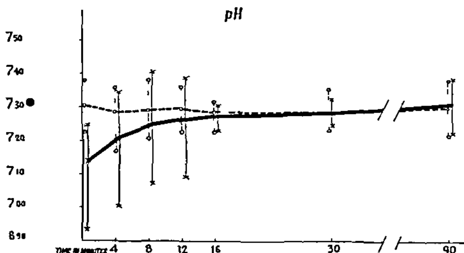
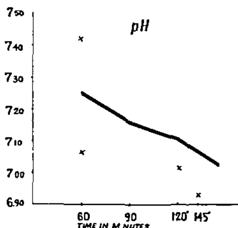


Table 2 pH as a function of the duration of ischaemia (the operated limb)



The anaesthesia given in 15 cases was combined thiopentone halothane-nitrous oxide The patients were intubated but breathed spontaneously The oxygen content of the anaesthetic gas mixture was 37 per cent The patients acid base balance was normal during surgery before the tourniquet was opened.

Table 3 pCO determinations after opening the tourniquet

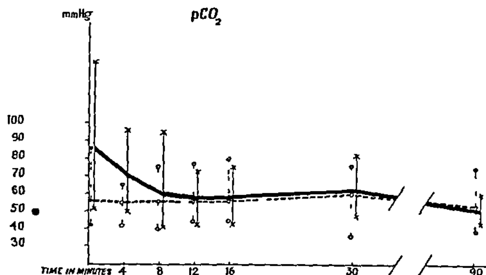
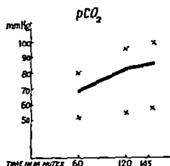


Table 4 pCO as a function of the duration of ischaemia (the operated limb)



Five patients were operated under plexus anaesthesia

Neither the temperature of the operated limb nor that of the patient was measured during the operation

The following determinations were made acidity (pH) PCO_ standard bicarbonate base excess (BE) pO potassium pyruvic acid lactic acid creatine phosphokinase (CPK) Blood specimens were taken from the cubital vein or the forearm vein both from the operated and from the contralateral arm in a following series

1 5 ml was drawn into a heparinised syringe for blood gas analysis care being taken that no air entered the syringe
2 10 ml was drawn into three separate tubes for determination
   a. of potassium,
   b of lactic and pyruvic acid proteins were precipitated with perchloric acid immediately after taking the sample and
   c of CPK.

Table 5 Standard bicarbonate determinations after opening the tourniquet

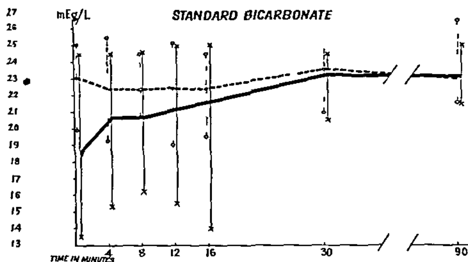
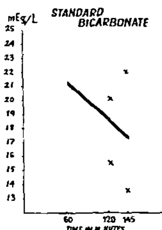


Table 6 Standard bicarbonate as a function of the duration of ischaemia (the operated limb)



The series of samples were taken at the following times

1 from the healthy upper limb only before anaesthesia All the following samples were taken simultaneously from both upper limbs
2 immediately after the opening of the tourniquet
3 4 min later (4)
4 4 min later (8)
5 4 min later (12)
6 4 min later (16)

Table 7 Base excess determinations after opening the tourniquet

BE

TIME IN MINUTES 4 8 12 16 30 90

Table 8 Base excess value as a function of the duration of ischaemia (the operated limb)

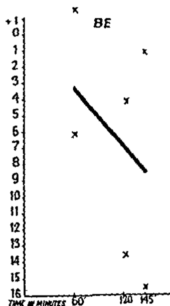


Table 9 pO determinations after opening the tourniquet The double line represents the averag values for patients under plexus anaesthesia (the operated limb)

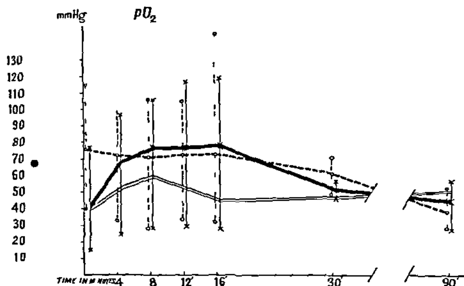
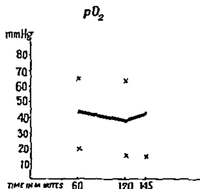


Table 10 pO values for the upper limb kept in ischaemia correlated with the duration of ischaemia



7 14 min later (30)

8 60 min later i e 90 min after opening the tourniquet (90')

The time of sampling was recorded It was impossible to avoid small deviations from the timetable

The laboratory tests were performed by the following methods

Blood pH pCO standard bicarbonate and base excess were measured in the blood pH meter devised by *Astrup et al* (1960)

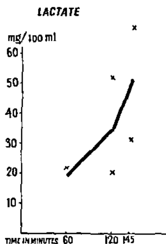
Table 11 Lactate determinations after opening the tourniquet

mg/100 ml LACTATE

90 80 70 60 50 40 30 20 10

TIME IN MINUTES 4 8 12 16 30 90

Table 12 Lactate concentration as a function of the duration of ischaemia (the operated limb)



An oxygen electrode was used for the pO_2 measurements (Radiometer 1963)

Lactate pyruvate and creatine phosphokinase were measured by the enzymatic method (Biochemia Boehringer 1961–1965)

An EEL flame photometer was used for the determination of potassium

The results are given in Tables 1–16

Table 13 Pyruvate determinations after opening the tourniquet

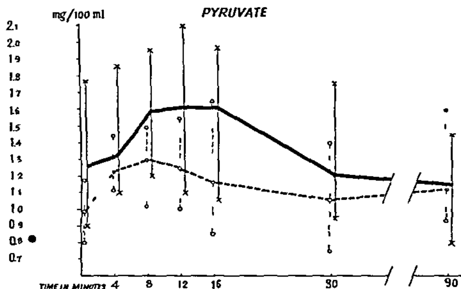
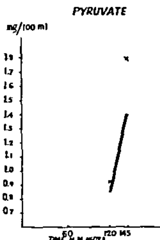


Table 14 Pyruvate as a function of the duration of ischaemia (operated limb)



DISCUSSION

Although the pH was distinctly lowered its mean minimum 7.14 was not particularly low The normal pH of venous blood is 7.30–7.40 (*Thorén* 1960) The pH value may fall much lower in some pathologic conditions (*Siggaard Andersen* 1963) Acidity may reach the level of

Table 15 Potassium determinations after opening the tourniquet

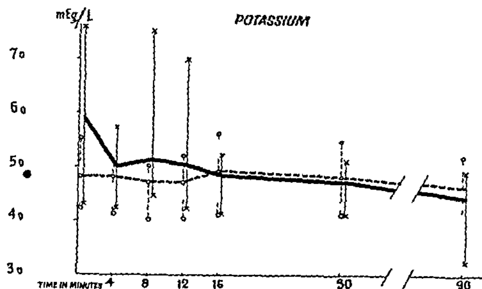
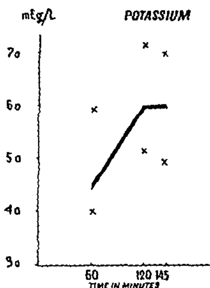


Table 16 Potassium values in correlation with the duration of ischaemia



the intact limb in 16 min The organism is thus well able to compensate the drop in the pH level following the opening of the tourniquet When the duration of ischaemia is prolonged the pH declines almost linearly It falls to close to 7.0 during ischaemia of over 2 hours This pH value is nearly the same as the intracellular pH (*Bittar* 1964)

The change in pCO_2 is not great for the length of the ischaemic periods though the mean 85 mm Hg is acidotic Elevation of the pCO value as a function of the ischaemic period is not steep The pCO may rise to over 150 mm Hg in some pathologic conditions (*Siggaard Andersen*) and therefore the values in the present study cannot be regarded as very high

Metabolic acidosis according to the standard bicarbonate and base excess values is not pronounced but its neutralisation is slower than the normalisation of pCO This is because the elimination of acid metabolites takes longer than the diffusion of CO from tissues to blood BE values of about —30 are measured in certain acidotic conditions (*Siggaard Andersen*) and the lowest mean —6 1 of our measurements was thus not very low

The partial pressure of oxygen does not drop as a function of time The processes which take place in an ischaemic limb after more than one hour are obviously partly anaerobic Considerable dissociation of oxygen of myoglobin occurs only after the pO_2 has fallen below 10 mm Hg Obviously some such situation has prevailed during ischaemia However the oxygen stores of myoglobin are not appreciably depleted judging by the pO values The percentage dissociation of myoglobin when pO is 40 is about 90 and there is consequently considerable oxygen supply left at that time

It is possible that after the tourniquet is opened the cells are incapable of taking up oxygen rapidly from the inflow of arterial blood to the tissue that has been ischaemic and that a part of the oxygen containing blood by passes the capillaries via shunts between arterioles and venules However the situation becomes normal fairly rapidly and after five minutes the pO values are the same in both upper limbs It must be remembered that the blood oxygen concentration in a patient under general anaestesia depends on the oxygen content of the gas mixture used The pO values for patients under plexus anaesthesia are therefore given separately These patients breathed only air

The potassium value rose to 6 1 mEq /l after two hours of ischaemia and appeared to persist at that level even with continued ischaemia The potassium value became normal rapidly after removal of the tourniquet *i e* within four minutes Only a small quantity of potassium seems to escape from the tissues in these operations and during ischaemia The intracellular potassium value is normally about 30 times the extracellular value The balance depends on the energy supply When the supply of energy is inhibited some potassium obviously

escapes from the cells A surgical injury can also contribute to the elevation of the potassium content This makes it all the more obvious that our measures did not greatly upset the energy balance of the tissues

The pyruvate values continued to rise after the opening of the tourniquet The explanation may be that glycolysis produced pyruvate from glycogen and that it is not disintegrated immediately by catabolism However the amount of glycogen produced energy is probably small since the elevated pCO inhibits the anaerobic decomposition of glycogen to lactate The lactate concentration remained elevated for some 30 min after the removal of the tourniquet but the values were not high The lactate concentration rises steeply as a function of the duration of ischaemia

The concentration of lactate and pyruvate are not directly correlated with the BE changes The reason for this phenomenon is discussed elsewhere (*Narvanen* 1966)

The observation period appeared to be too short for CPK determinations

CONCLUSIONS

Although a metabolic balance prevails between tissues and blood its dynamic character does not warrant far reaching conclusions

Ischaemia induced acidosis is not particularly severe It displays features of both metabolic and respiratory acidosis The acidosis is neutralised rapidly as the circulation returns to normal

Anoxia during ischaemia is corrected rapidly It seems that there is no large demand on the oxygen reserves of the myoglobin in the muscular tissue

In view of the paucity and the deviation of the findings it would be venturesome to draw conclusions on the basis of the lactate pyruvate ratio *The rather slight increase in the potassium value shows that both* the ischaemia and the operation caused only a slight tissue trauma from the energy standpoint

Transfer of energy between muscle cell and nerve cell is difficult to discuss on the strength of these results

As the limb to be operated on is hypothermal because of ischaemia (*Dery et al*) the metabolic processes slow down When our results are compared with known characteristics of muscle metabolism it may perhaps be said that muscular tissue at any rate has sufficient energy

reserves to maintain post ischaemic recuperation processes when the ischaemia is as long as it was here

That acidotic blood with a high CO_2 content rushes into the systemic circulation at the moment ischaemia is discontinued may be of clinical significance The elevated pCO_2 may aggravate the fall in blood pressure which is always demonstrable when the tourniquet is removed and the vessels of the exsanguinated limb fill with blood The high CO_2 concentration probably causes vasodilatation and exacerbates the irritability of the myocardium If the myocardium is sensitised to arrhythmia in advance *e g* by adrenalin or halothane such an increase in acidosis may lead to a functional cardiac disorder This is particularly true of patients who have previously been acidotic have poor pulmonary function and a previously elevated CO_2 value However the acidosis after the ischaemic phases described here is so mild and of such short duration that it can hardly harm a patient in good condition

SUMMARY

The metabolic changes caused by tourniquet ischaemia were studied in 20 patients subjected to reconstructive operation on the upper limb All the determinations were made in venous blood Moderate acidosis was established in the ischaemic limb The condition was metabolic acidosis in which the carbon dioxide content was elevated The acidosis increased as a function of the duration of ischaemia but disappeared rapidly when the circulation was normalised The blood potassium rose to an average of 6 1 mEq/l The lactate and pyruvate content increased as a function of the duration of ischaemia but neither reached high levels Both the ischaemia and the surgical intervention seem to have caused only a slight and rapidly corrected tissue injury as far as energy balance is concerned

RESUME

Les modifications metaboliques causees par ischemie au tourniquet ont ete etudiees pour 20 malades chez lesquels il a eté procédé a une operation reconstructive du membre superieur Toutes les déterminations ont eté faites a partir du sang veineux Une acidose modérée a été constatee dans le mebre ischemique Il s agissait d une acidose métabolique dans laquelle la teneur en barbone dixide était plus élevée L acidose s est accrue en fonction de la duree de l ischemie mais disparut rapidement dès que la circulation fut a nouveau normalisée Le potassium du

sang s'est eleve a une moyenne de 6 1 mEq/l La teneur en lactate et pyruvate s'est accrue en fonction de la duree de l'ischemie mais n'a jamais atteint un niveau tres élevé Tant l'ischemie que l'intervention chirurgicale ne semblent avoir cause qu'une faible lesion tissulaire rapidement corrigee en ce qui concerne l'equilibre de l'energie

ZUSAMMENFASSUNG

Die metabolischen Veranderung die durch Blutleere bei 20 Patienten entstanden an denen eine Wiederherstellungsoperation der oberen Gliedmasse ausgefuhrt worden war wurden untersucht Alle Bestimmungen wurden an venosem Blut gemacht Moderate Acidose wurde an der ischamischen Gliedmasse festgestellt Der Zustand war eine metabolische Acidose in der der Carbondioxidinhalt erhoht war Die Acidose nahm als eine Funktion der Dauer der Blutleere zu verschwandt aber rasch wenn die Zirkulation wiederum normal wurde Der Blutkalium inhalt stieg zu einem Durchschnitt von 6 1 mEq/l Der Laktat und Pyruvatinhalt stieg als eine Funktion der Dauer der Ischaemie aber keiner von beiden erreichte hohe Werte Sowohl die Blutleere als auch der chirurgische Eingriff scheinen nur einen leichten und rasch korrigierten Gewebsschaden hinsichtlich des Energiegleichgewichtes hervor gerufen zu haben

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COLLES' FRACTURE

OPERATIVE TREATMENT, INDICATIONS AND RESULTS

By

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Colles' fracture, in Scandinavia generally termed fractura radii typica, belongs to the most frequent type of fracture. During the last five years 1961–1965 the Emergency Service registered 57426 fractures, a total of which 10729, or about 18.7 per cent, were fractura radii typica. A number of reports have been made on the results of conventional treatment of this type of fracture, among others the works of the Scandinavians *Nissen-Lie* (1939), *Rosen* (1947), *Madsen* (1949), *Wicklund & Mullern-Aspegren* (1956) and *Lidstrom* (1959).

Nissen-Lie's grouping of fractures of the lower end of the radius has been generally accepted as a classification basis in the Scandinavian reports:

I. Fractures on the passage between the scapus and the lower end of the radius, most frequent in children one to fifteen years of age.
II. Epiphysiolysis in children and youths ten to twenty years of age.
III. Fractures through the lower end of the radius without dislocation.
IV. Fractura radii typica (Colles') with dorsal and volar dislocation.
V. Comminute fractures with one or more communications to the joint.
VI. Isolated fractures of the styloid process of the radius.
VII. Fractures with volar dislocation (Smith's).

The following are the results of Nissen-Lie's report, which covers 282 re-examined cases classified as above:

- I 45 cases All healed without lasting injury
- II 32 cases All healed without lasting injury
- III 57 cases 52 healed without lasting injury and 5 healed with a slight radial deviation
- IV V 143 cases of dislocated and partly comminute fractures of which 133 were controlled about one year after the time of injury
  - 103 (73 per cent) were free of symptoms and had full mobility
  - 16 (12 per cent) had slight radial deviation
  - 12 (9 per cent) expressed pain (only by use)
  - 9 (7 per cent) had reduced mobility
  - 8 (6 per cent) showed marked radial dislocation
- VI 10 cases All free of symptoms
- VII 5 cases All healed with a slight radial deviation otherwise free of symptoms

In his report *Nissen Lie* classifies 26 cases healed with slight radial deviation as satisfactorily healed thus giving an extremely low number of unsatisfactorily healed cases representing only about 5 per cent of the total and referring mainly to the displaced and comminute fractures in the groups IV and V

Madsen reports a redisplacement of 39 per cent of the cases in group IV and 75 per cent in group V

In addition *Lidstrom* stresses the evident connection between the intra articular fractures and the unsatisfactory results in his report representing 8 per cent of the total number of cases

On the other hand *Bacon & Kurtzke* state that the average disability was 24 per cent in a study made of 2132 cases of Colles fracture from the New York State Workmen s Compensation Board while only 2 9 per cent of the cases were judged to have no permanent disability However X ray examination of the anatomical results usually reveals a somewhat different picture

In Nissen Lie s groups IV and V 70 per cent of the cases showed ideal initial reduction in which a total of 60 per cent had a 4 mm or more shortened radius as a final result Furthermore 80 per cent of the cases in Nissen Lie s groups IV and V showed varying degrees of clinical deformity of the hand in eight cases characterized as severe and in twenty six cases as light In comparison Lidstrom s total material shows redisplacement in 28 per cent of the cases

These facts indicate as commonly accepted that poor anatomical or

cosmetic results are not necessarily connected with unsatisfactory functional results

Lidstrom draws the following conclusions in his report

1. The prognosis was less favourable for intra articular fractures than for other types of fractures
2. Final deformity increased the risk of impaired function
3. Posttraumatic causalgia was to a certain degree permanent with consequent loss of function
4. Residual laxity in the distal radio-ulnar joint increased the risk of reduced function

In connection with the second paragraph of the conclusions it seems natural to consider alternative precautions to prevent deformity during or after reunion for example through operative corrections

Surgical interventions have been performed on this basis partly as osteotomies to correct deviations partly by bone grafting to correct disproportions between the radius and the ulnae in cases of shortened radius These procedures where grafts from the distal end of the ulnae or from the distal end of the upper radial fragment are wedged into the osteotomy of the lower end of the radius have been described respectively by *Campbell* (1937) and *Durman* (1937) Ulnar pinning to prevent displacement was described by *De Palma* (1950) and closed medullary pinning by *Rush* (1954) Other operations have also been performed in order to improve mobility for instance through resection of the lower end of the ulnae according to the original Darrach method

In his report *Lidstrom* recommends the following directions for operative correction

1. The deformity should be severe
2. Sufficient time must have elapsed after time of injury
3. There should be no symptoms of posttraumatic disturbances or nerve injuries
4. There should be no comminution of the articular surface or arthritis of the radio carpal joint
5. Operative correction of radio ulnar instability is only indicated in cases where the capitulum ulnae is displaced out of the ulnar notch

After thorough investigation A Kristiansen has worked out a method to prevent or correct final deformity of the radius The method is based

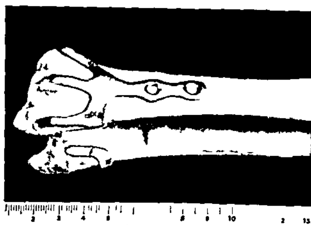


Figure 1 Photo of the K splint in situ on a radial bone pictured with a mirror as background thus showing both the dorsal and ventral side

on the principle of restoring the anatomical conditions by bone grafting combined with an internal fixation of the fragments by means of a specially constructed surgical appliance

In our opinion the method will ensure better results for operations in the region of the radio carpal joint although the close anatomical relations in this area make surgical intervention rather complicated compared to operations on fractures adjacent to other joints of the extremities

Close anatomical studies indicated the construction of an appliance later called the K splint which is hand shaped with three fingers on the dorsal side and one finger on the radial side (Figure 1) The finger on the radial side like a thumb bends around the styloid process keeps this in position and continues on the other side to support the volar aspect of the radius

The original intention was to locate the three fingers between the tendon channels

Due to deformity and loss of structure and bone substance the exact indicated positions of the fingers are often difficult to obtain Practice proves however that this does not influence the final result

The K splint is produced in three sizes from an alloy which like the original Vitallium consists of cobolt chromium and molybdenum In addition there is a T shaped appliance specially constructed to support the volar face of the radius in cases of Smith s fracture

A retractor has also been constructed one for each hand This re

tractor allows a steel wire inserted between the radius and the surrounding soft tissues to be stretched without interfering with X ray examinations during operation

Furthermore a pair of modified Lambotte s forceps adjusted to the broad volar aspect of the radius on one side and to the splint on the other side is recommended to lock the splint to the radius A pair of standard forceps for final adjustments of the K splint s fingers is also required

THE OPERATION

The skin incision starts at the base of the thenar and continues with a slight dorsal curve along the tendon of the long abductor and short extensor muscles of the thumb Then on reaching the dorsal side of the radius the incision is slightly curved in a volar direction up to a handsbreadth above the radio carpal joint The fascia is divided along the superficial radial nerve which together with its branches to the thumb is exposed up to the crossing with the brachio-radial muscle Here the nerve leaves the fascial layer and is to be exposed by a pair of scissors with edge turned dorsally to divide the connective tissue between the brachio radial and extensor carpi radial muscles The nerve is retracted dorsally The brachio radial muscle is loosened by subperiostal dissection from its insertion at the styloid process of the radius and retracted in volar direction The periosteum is divided corresponding to the edge of the radius and the fragments exposed by careful dissection in the subperiostal space

Having obtained a good general view of the fracture and the crossed zone of bone a suitable block of cancellous bone (without the cortical layer) is chiselled out of the iliac crest and trimmed to replace the crossed part of the bone The K splint is fixed to the proximal fragment by two screws The fingers of the splint will then keep the distal fragments and the bone in position If necessary adjustments are made by the insertion of small cancellous bone grafts

During the first ten days of aftertreatment a simple volar splint is recommended After the sutures are removed a plaster cast is applied for 8–12 weeks

X ray examinations with a carefully standardized technique are carried out during the operation two to seven days after the operation and repeated every two or four weeks until the fracture is consolidated

THE CASES

This report covers a total of twenty six patients operated and followed up by Amund Kristiansen reexamined and evaluated by Einar Gjersöe Data are insufficient in three cases all referring to older patients that died of other reasons during the follow up period

The remaining twenty-three cases consist of Twenty two patients with Colles fracture and one Smith s fracture

The age of the three male and twenty female patients varied from thirty to seventy two years giving an average age of fifty five years

Indications

I Six patients had impaired function and/or pains as result of mal united fractures Operations were performed between 41 and 189 days after injury

II Seventeen patients had redislocated fractures which were operated before the end of the reunion period These patients were operated upon between 3 and 29 days after injury

Complications

I Three cases of lesion of the dorsal skin innervation of the thumb immediately treated with nerve sutures

II Two cases of superficial infection

III In four cases the K splint was removed in one case because it loosened after reunion and in one case because it broke In two cases the splint became too long after a second reduction of the length of the radius thus interfering with the free movements of the hand

Reexamination

The average observation time in this report is four years and five months varying from two years and ten months to nine years and six months

At reexamination the following results were evaluated

1 Anatomical results
2 Mobility
3 Pains

The patient s uninjured hand has been used as an evaluation basis for the anatomical results *In cases of previous fractures of the other*

hand the average values of this report s uninjured hands have been used for comparison

Articulation surface in frontal projection 116

Articulation surface in lateral projection 81

Level difference between the point of the styloid process of the radius and the capitulum ulnae (called d) 12 mm

These values correspond with the normal values indicated by de Palma who states 120 /105 in frontal projection and 89 /67 in lateral projection with an average of respectively 113 and 79

Like Nissen Lie and others we have used the difference in distance (distance = "d) between the top of the styloid process of the radius and the plane through the distal articular surface of ulnae as one method to measure shortening and redisplacement

Usually the shortening is located on the radial side and in these cases the difference in d gives the actual shortening

As this method of measuring the reduced length does not cover a possible shortening on the ulnar side of the radius we have consequently measured the ulnar shortening or the distance between the distal ulnar corner of the radius and the plane through the distal articular surface of the ulnae and for practical reasons graded the distance as follows

+ 1–5 mm
++ 6–10 mm
+++ more than 10 mm

The same system has been used in order to grade the volar displacement by measuring the distance between the most prominant part of the volar displaced fragment and the volar aspect of the radius and the dorsal displacement by measuring the distance from the most prominent part of the dorsal-dislocated fragment to the dorsal aspect of the radius

Final anatomical results

The results of the operations performed and covered in this report have been divided into the following groups

I Excellent anatomical results This group consists of seven patients all with joint surfaces differing less than 10 in one or both projections from the uninjured hand In four cases the divergence is less than 5 and in all cases there is none or only minor reduction of "d (less than 5 mm) and no ulnar shortening

II Good anatomical results Six patients belong to this group In these cases the articulation surface has a divergence of maximum 20 in one or both projections and the reduction of d is less than 10 mm The ulnar shortening does not exceed 5 mm (called +) and the angle of the articulation surface is less than 90 in the lateral view

III Fair anatomical results This group includes four patients all with an ulnar shortening of the radius not exceeding 10 mm (called ++) In one case the articulation surface has a divergence of 24 in the lateral projection In the other cases the divergence is less than 20 in one or both projections In two cases the angle of the articulation surface is more than 90° in the lateral view

IV Poor anatomical results In this group which consists of six patients the result may be characterized as less favorable than in group III All patients have some dislocation ad axim In five cases the angle of the articulation surface is not satisfactory

Function

In cases that permit such a comparison the evaluation of the mobility has been based on the movements of the uninjured hand In the other cases the normal rates given by the Committee of Medical Rating and Physical Impairement (J A M A spec ed febr 15 1958) have been used in comparison According to this rating and in order to measure the function of the wrist the lasting impairment has been judged without taking into consideration the patient s subjective troubles The following movements have been measured Dorsal volar radial and ulnar flexion pronation and supination These are the results

0– 5 per cent mobility impairment eight patients
6–10 per cent mobility impairment ten patients
11–25 per cent mobility impairment five patients

Subjective Symptoms

Of the thirteen patients in groups I+II three had grumbling in the hand with weather changes and three reported some hypoaesthesia on the dorsum of the thumb All patients in these groups stated that they had full working ability

Of the ten patients in groups III+IV one patient had difficulty in

holding heavy things in maximal pronation and minimal supination of the hand This patient presented fracture and nerve injury at the time of injury

One patient a waitress reported that she was unable to carry trays with her hand in supination although she had full mobility in the hand In two cases minor sensory nerve disturbances were observed on the dorsal side of the thumb

One patient complained about lasting pains in the injured wrist caused by arthritis and arthrosis This patient sixty one years of age has a full time job as a cashier The other patients consider their minor defects to be of no importance and are all consequently fully employed

On the whole twenty one patients are very well pleased with the results obtained and consider their hands to be as good as before the injury Only two patients do not belong to this satisfied group namely the one who has certain difficulties in performing her job as a waitress and one who is not satisfied because of pains

DISCUSSION

The above cases with a few exceptions represent severe and complicated fractures which have all healed with satisfactory functional results despite proved or indicated unsatisfactory results from earlier treatment

The technically difficult method demands however both experience and skill from the operator

Operations of this kind are specially difficult to perform between two and six weeks after the time of injury because of the fragility of decalcinated bone or in other words when indications clearly show the necessity for operation Case determination and operating performance at an earlier stage will however reduce the degree of difficulty and save the patient s time These are our general remarks concerning the conditions which in our opinion should be taken into consideration

The stability of a fracture in the lower end of the radius of an unloaded arm is based upon

A The muscles and their acting on the fragments
B The fracture plane s angle to the axis of the radius which influences the leverage of the muscles

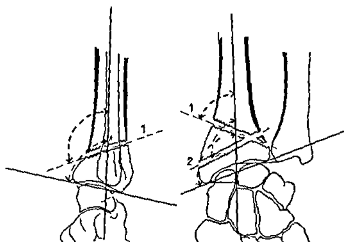


Figure 2 Drawing of a radial fracture In case of fractures with fracture line 1 the action of the pronator muscles especially the quadratus may draw the scapus fragment towards ulnae while the distal fragment tangenting ulnae at the distal radio ulnar joint remains in situ turning only a few degrees around the dorso ventral axis thus fracture line 2 the action of the pronators force the scapus fragment to grasp the distal fragment thus helping to keep this in position and to stabili e the fracture

The extensor and flexor muscles pull the distal fragment mainly in proximal direction but to a certain degree also in dorsal or ventral direction according to the position of the hand and the fragments

The general action of the pronators and supinators in relation to the movements of the hand and forearm is well known Less considered however, is the action of the pronator quadratus, and to a certain degree the action of the pronator teres which both try to pull the scapus fragment of the radius towards ulnae The result of this action is of great importance to the stability of the fracture

A 90 or more angulation of the fracture line in frontal view increases stability while a smaller angle reduces stability On the above outline (Figure 2) of a Colles fracture fracture line no 1 of the frontal view shows that the scapus fragment may be drawn ulnar until its distal ulnar corner contacts ulnae while the distal fragment tangenting ulnae at the distal radio ulnar joint remains in position turning only a few degrees around the dorso ventral axis The dislocated fracture seems in other words to be a radial displacement of the distal fragment while it actually is an ulnar displacement of the proximal fragment



Figure 3 A A typical Colles fracture case no 14



Figure 3 B The result after three weeks of treatment in a plaster cast



Figure 3 C The final result

Fracture line no 2 shows clearly how the proximal fragment will contact the distal fragment and keep this in position

The lateral view of the fracture indicates how an angle of more than 90 facilitates a displacement of the distal fragment in the dorsal direction In the same way an angle less than 90 lightens a displacement in the ventral direction

A rough fracture surface will of course increase the friction but the stability *of a fracture depends first of all on the size of the crossed* zone of bone This is usually wedge shaped with the base on the dorsal side and the edge on the ventral side a shape due to the direction of the injury and to the thin crisp cortical layer on the dorsal side The thick strong cortical layer on the ventral side however usually prevents the distal fragment from being impacted in the proximal one which occurs quite often on the dorsal side

On the whole one may say that the resorbtion of bone increases with

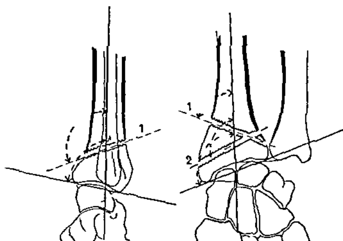


Figure 2 Drawing of a radial fracture In case of fractures with fracture line 1 the action of the pronator muscles especially the quadratus may draw the scapus fragment towards ulnae while the distal fragment tangenting ulnae at the distal radio ulnar joint remains in situ turning only a few degrees around the dorso ventral axis thus fracture line 2 the action of the pronators force the scapus fragment to grasp the distal fragment thus helping to keep this in position and to stabilize the fracture

The extensor and flexor muscles pull the distal fragment mainly in proximal direction but to a certain degree also in dorsal or ventral direction according to the position of the hand and the fragments

The general action of the pronators and supinators in relation to the movements of the hand and forearm is well known Less considered however is the action of the pronator quadratus and to a certain degree the action of the pronator teres which both try to pull the scapus fragment of the radius towards ulnae The result of this action is of great importance to the stability of the fracture

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ing combined with an internal fixation of fragments by means of a specially constructed vitallium appliance called the K splint

Twenty six patients have been operated upon according to the above method

The final results have been evaluated both anatomically and functionally in seven cases characterized as excellent in six cases as good in four cases as fair and in six cases as poor The approximate functional impairment of the total number of cases is about 7 7 per cent

The authors of this article conclude that the results achieved through the method described justify further work with the method

RESUME

Cet article decrit une methode elabores pour prevenir ou corriger une *deformite finale du radius apres lesion provenant d une fracture* La methode se base sur le principe de la restauration des conditions anatomiques par greffe osseuse combinee a une fixation interne des fragments au mayen d un dispositif en vitallium specialement construit appele éclisse K 26 malades ont éte operées par cette methode

Les resultats finaux ont ete caracterises au double point de vue anatomique et fonctionnel comme excellents dans sept cas bons dans six cas passables dans quate cas et mauvais dans six cas L affaiblissement fonctionnel a éte approximativement de 7 7 per cent si l on considère le nombre total des cas

Les auteurs de l article arrivent a la conclusion que les resultats obtenus par la methode decrite justifient la poursuite des travaux avec cette méthode

ZUSAMMENFASSUNG

Diese Arbeit beschreibt eine Methode die entwickelt wurde um eine endgültige Deformitet des Radius nach Bruchschaden zu verhindern oder zu korrigieren Die Methode ist auf dem Prinzip der Wiederherstellung anatomischer Verhaltnisse mittels Knochenverpflanzung kombiniert mit einer internen Fixation der Fragmente mittels einer speziell konstruierten Vitalliumschiene genannt K Schiene gegrundet 26 Fälle sind durch diese Methode operiert worden

Die Endresultate wurden sowohl anatomisch als auch funktionell bewertet und sieben Fälle wurden als ausgezeichnet sechs Fälle als gut vier Fälle als mittelmassig und sechs Fälle als schlecht angesehen Die ungefahre funktionelle Herabsetzung der Gesamtanzahl der Fälle ist 7 7 per cent

Die Verfasser dieser Arbeit schliessen dass die mit der beschriebenen Methode erreichten Ergebnisse weitere Verwendung der Methode recht fertigen

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THE POSSIBLE IMPORTANCE OF THE PSOAS MUSCLE FOR STABILIZATION OF THE LUMBAR SPINE

By

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Received 24 xii 66

By intravital discometry it is possible to calculate the load on a particular lumbar disc This load is correlated to the weight of the subject and the position of the body (21 24)

In the forward stooping and weight lifting positions the results were lower than those theoretically calculated by earlier investigators (19 25 30) but more in agreement with knowledge of the ultimate strength of the vertebral bodies (5 10 14 16 25 28) (Table 1)

In the upright standing and sitting positions however the measurements showed that the discs have to carry relatively high loads (21 24) It is the purpose of this paper to discuss these findings with special reference to the stabilizing function of the vertebral portion of the psoas muscle

ELECTROMYOGRAPHIC INVESTIGATIONS

Many authors have demonstrated that in the upright positions the sacro spinalis group of muscles are inactive (1 6 12 15 19 20 23 27) but since the body in these positions sways somewhat occasional bursts of activity were noted in long term studies by *Boman & Jalavisto* (3) On forward leaning these muscles increase their activity (12 20 23)

The abdominal muscles were investigated by *Floyd & Silver* (11) and it was found that they too were for all practical purposes inactive in these positions with the exception of some slight activity in the internal oblique muscle

The vertebral portion of the psoas muscle has received little interest and hardly any reports on its function for the spine are found in the literature (18) *Close* (7) and *Basmajan* (2) investigated the muscle

Table 1 Approximate load in kg on the third lumbar disc in different positions in individuals of varying bodyweights

Weight of subject (kg) Position of body	50	60	70	80	90	100
			load on the disc (kg)			
Upright sitting unsupp	110	126	142	158	174	190
Upright standing	75	87	99	111	123	135
Reclining (lateral decubitus)	55	63	71	79	87	95
Reclining (relaxed supine)	15	15	20	20	25	25
Sitting + forward tilting of 20	145	168	191	214	237	260
Sitting + forward tilting of 20 and 10 kg load in each hand	226	249	270	295	317	340
Standing + forward tilting of 20	110	129	148	167	186	205
Standing + forward tilting of 20 and 10 kg load in each hand	177	195	215	234	262	287

with needle electrodes near the hip joint in order to elucidate its action on this joint Recently an investigation was performed (23) by which it was demonstrated that the psoas muscle showed electromyographic activity in the upright sitting and upright standing positions (Figures 1 and 2) It was also noted that in the standing position the activity increased when leaning forward 20 (Figures 2C and D) In the sitting position there was no such increase while leaning forward but the activity while sitting upright was higher than that when standing upright (Figures 1C and D) This can be explained by the finding that in the upright sitting position the lumbar spine is somewhat flexed in comparison to the upright standing position (29 31)

THE LINE OF GRAVITY

According to previous investigators (1 4 8 9 29 31) the line of gravity falls in most subjects through the center of the third lumbar disc in the upright standing position and about 4 cm in front of the center of the disc in the upright sitting position Thus muscular or ligamentous forces or both must be taken into consideration to explain the relatively high loads found in these positions by intravital discometry

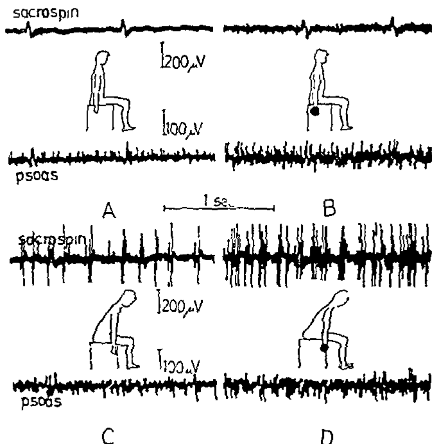


Figure 1 *The electromyographic activity of the vertebral portion of the psoas major muscle right side in a male age 24 years A) upright unsupported sitting B) upright unsupported sitting 10 kg in each hand C) sitting and forward leaning twenty degrees by flexion in the hip joints D) sitting and forward leaning twenty degrees by flexion in the hip joints and holding 10 kg in each hand The electromyographic activity of the sacro spinalis muscles is also shown in the different positions*

since gravity alone would give less load In a man who weighs 70 kg about 40 kg is the weight of the part of the body above his third lumbar disc according to *Ruff* (28) (Table 2)

THE STABILITY OF THE SPINE

The spinal column which serves as a sustaining rod for the maintenance of the upright position of the body was considered by *Lucas*

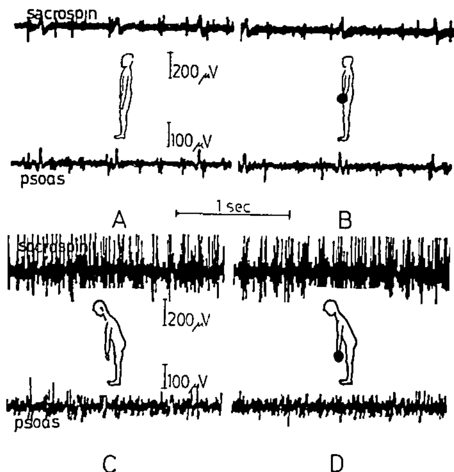


Figure 2 The electromyographic activity of the vertebral portion of the psoas major muscle right side in a male age 24 years A) upright standing at ease B) upright standing 10 kg in each hand C) standing and forward leaning twenty degrees by flexion in the hip joints D) standing and forward leaning twenty degrees by flexion in the hip joints and holding 10 kg in each hand The electromyographic activity of the sacro spinalis muscles is also shown in the different positions

& *Bresler* (17) to have both an intrinsic and an extrinsic stability Intrinsic stability is provided by ligaments and discs which bind together the alternating vertebral bodies while extrinsic stability is provided by the paraspinal and trunk muscles

Considered alone the spinal column and its ligaments behave like a modified elastic rod When it is fixed at the base its critical load—*i e* the greatest load it can sustain without buckling is only 2 kg (17) Therefore the stability of the spine in the living human being is de

Table 2 Approximate formulas for load (P) on lumbar discs in different positions

Position		
Upright sitting with arms and back unsupported	$P_{sitt} = P_0 + 2.8\,W$	$P_0 \approx 30$ kg
Upright standing	$P_{stand} = P_0 + 2.1\,W$	$P_0 \approx 15$ kg
Reclining (tilted on side lateral decubitus)	$P_{recl} = \frac{P_0 + 2.8\,W}{2}$	$P_0 \approx 30$ kg
Reclining (relaxed supine)	$P_{recl} = P_0$	$P_0 \approx 15$ kg
Sitting + forward leaning α degrees	$P_{sitt} = P_0 + 2.8\,W + 3.6\,W \sin\alpha$	$P_0 \approx 30$ kg $\alpha = 10$–20
Standing + forward leaning α degrees	$P_{stand} = P_0 + 2.1\,W + 3.6\,W \sin\alpha$	$P_0 \approx 15$ kg $\alpha = 10$–20

P_0 = intrinsic pressure W = weight above the level measured (59 per cent of bodyweight above L IV 57 per cent above L III and 55 per cent above L II)

pendent on the extrinsic support provided by the trunk muscles The lack of inherent intrinsic stability of the vertebral column and the importance of the trunk muscles are clearly demonstrated if one tries to hold an unconscious person upright

DISCUSSION

Intravital discometry has demonstrated that the load on the middle lumbar discs varies with the position of the subject and weight of the body (21 24) The results of these measurements are summarized in Tables 1 and 2

It is unlikely that gravitation forces are sufficient to explain the relatively high loads in both upright standing and sitting positions found from these measurements

Previous electromyographic investigations on the activity of the sacro spinalis and anterior abdominal muscle groups demonstrated that all these are with few occasional exceptions inactive in these positions (1 3 6 11 12 15 19 20 23 27 29)

On the other hand it was recently demonstrated that activity existed in the upright positions in the vertebral portion of the psoas muscle

(23) This muscle should then be considered in providing some of the stability of the lumbar spine By its activity it also increases the load on the discs in these positions

Lucas & Bresler (17) demonstrated that ligamentous forces are too small to provide the necessary stabilization and discometry in anaesthetized individuals resulted in pressure values corresponding to a load of about 30 kg This is the magnitude of force that could result from tension in the ligaments This verified *Petter* s (26) and *Nachemson* s (22) findings on autopsy material

With our present knowledge it is possible to approximate the amount of force which the vertebral portion of the psoas muscle compresses the lumbar spine in some positions

If we first consider the load on the lumbar disc in the upright standing position it can be expressed by the following equation (Table 2)

eq (1) $$P_{standing} = 15 + 2\,1W$$

where W is the bodyweight above the lumbar disc measured and 15 corresponds to the intrinsic load that force resulting from the ligaments When the body is in equilibrium in the upright standing position there is only occasional activity in the sacro spinalis muscles (15 27) while the activity of the psoas muscle seems less variable (23)

When standing the line of gravity falls through the center of the third lumbar disc (4 9) and the force by which the psoas muscles (P_{psoas}) compress this disc in a man of 70 kg thus can be calculated using the above mentioned equation (1) In this case W = 40 kg $P_{standing}$ = 99 kg and thus

eq (2) $$P_{psoas} = P_{standing} - W - 15 = 99 - 40 - 15 = 44 \text{ kg}$$

The bodyweight is calculated according to *Ruff* (28) who stated that 59 per cent of the bodyweight is above L 4 and 57 per cent above L 3

Activity in the sacro spinalis group of muscles which probably occurs when the center of gravity moves forward due to swaying (3) will lessen the force by which the psoas muscles compress the disc

In the upright unsupported sitting position the load on the third lumbar disc in a 70 kg man is 142 kg according to Tables 1 and 2 In this position some light activity was found in the sacro spinalis group of muscles in most cases by *Schoberth* (29) but only in exceptional cases by *Nachemson* (23) and *Akerblom* (31) The distance from the midpoint of the nucleus pulposus to the midpoint of the attachment of the back muscles is approximately 5 cm according to *Waris* (30)

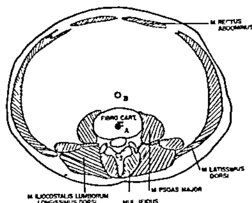


Figure 3 Schematic drawing of the vertebral portion of the psoas major muscle and its relation to the third lumbar disc The line of gravity in the standing position probably falls through the center of the disc (A) In the upright unsupported sitting position this line falls in front of the center of the disc (B)

and *Perey* (25) The line of gravity falls about 4 cm in front of the nucleus of the disc (4 8 31) If we assume that the midpoint of the psoas attachment is 1.5 cm behind the center of the disc (Figure 3) the force derived from the activity of the psoas muscle (P_{psoas}) and of the sacro-spinalis muscles (P_{sacro}) can be calculated from the following equations

eq (3) $$P_{psoas} + P_{sacro} + W = P_{sitting} - P_0$$

eq (4) $$P_{psoas}\, a_1 + P_{sacro}\, a_2 = W\, a_3$$

if $a_1 = 1.5$ cm $a_2 = 5$ cm $a_3 = 4$ cm (Figure 4) $W = 40$ kg and $P_0 =$ 30 kg then

$$P_{psoas} + P_{sacro} = 142 - 40 - 30 = 72$$

$$1.5\, P_{psoas} + 5\, P_{sacro} = 160$$

$$P_{psoas} \approx 58 \text{ kg} \quad P_{sacro} \approx 15 \text{ kg}$$

In some subjects no activity was found in the sacro-spinalis group of muscles (23 29) According to the eq (3) the compressive force exerted by the psoas muscles then amounts to 72 kg In these cases the line of gravity will tend to move closer towards the center of the disc and according to eq (4) this line will now fall only 2.7 cm in front of the center of the disc instead of 4 cm as in the example given above From these examples it should be clear that if the line of gravity is located 2 cm or 4 cm in front of the center of the disc the compressive

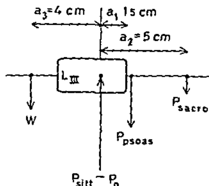


Figure 4 Schematic drawing of the forces and lever arms around the center of the third lumbar disc in the upright sitting position

W	= *Body weight above the disc*
P_0	= *The intrinsic load on the disc*
P_{sacro}	= *Force derived from activity of the sacro spinalis muscles*
P_{psoas}	= *Force derived from activity of the psoas muscles*
P_{sitt}	= *Total load on the disc in the sitting position*
a_1	= *distance from center of psoas muscles to center of disc*
a	= *distance from sacro spinalis muscles to center of dis*
a_3	= *distance from line of gravity to center of disc*

force of the sacro spinalis muscles (P_{sacro}) is small in comparison to that of the psoas muscle (P_{psoas})

At the third lumbar level the crossectional surface area of the psoas muscle is nearly 25 cm (Figure 3) According to *Michele* (18) it is a unipennate muscle which is able to develop a force of between 6 and 10 kg/cm (*Hettinger* (13)

With this knowledge in mind the above mentioned figures for the compressive force exerted by psoas muscles in the upright standing and sitting positions fall within reasonable limits

It should be remembered however that these compressive forces vary somewhat since occasional activity in both the sacro spinalis and anterior abdominal muscles are registered

SUMMARY

In the upright sitting and standing positions the lumbar spine must be stabilized by extrinsic forces since it has been demonstrated that the intrinsic ones are inadequate

It is possible that this stabilization in the upright positions is provided to some, probably a major extent by the vertebral portions of

the psoas muscles It can be calculated that in upright standing this force is about 40 kg and in upright sitting about 60 to 70 kg In both examples possible activity in the sacro spinalis group of muscles will tend to diminish the forces exerted by the psoas muscles

RESUME

Dans les positions assise redressee et debout la colonne lombaire doit etre stabilisee par des forces extrinseques puisqu il a ete demontre que les forces intrinseques sont inadequates

Il est possible que la stabilisation dans les positions redressees est assuree par une extension probablement majeure des portions vertebrales des muscles psoas

On a calcule qu en position redressee il faut une force d environ 40 kg et en position debout entre 60 et 70 kg Dans les deux exemples une activite eventuelle du groupe des muscles sacro spinalis tend a diminuer les forces exercees par les muscles psoas

ZUSAMMENFASSUNG

In der aufrechten sitzenden und stehenden Haltung muss die Lendenwirbelsaule von ausseren Kraften stabilisiert werden da es sich erwiesen hat dass die inneren Krafte nicht hinreichend sind

Es ist moglich dass diese Stabilisierung in aufrechter Haltung zu einigem wahrscheinlich grosserem Ausmasse von dem vertebralen Anteil des m psoas besorgt wird Man kann berechnen dass diese Kraft bei aufrechtem Stehen ungefahr 40 kg und beim aufrechten Sitzen ungefahr 60 bis 70 kg betragt Bei beiden Stellungen wird eine mogliche Aktivitet der sacro spinalen Muskelgruppe die Neigung haben die von den Psoasmuskeln ausgeubten Krafte zu vermindern

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IN VITRO INCORPORATION OF S^{35} SULFATE IN CHONDROSARCOMATOUS TISSUE

By

HARRY BOSTRÖM[1] ULF FRIBERG K. SUNE LARSSON & ULF NILSONNE[3]

Received 3 ii 67

INTRODUCTION

Radical surgery is at present the only appropriate form of therapy for chondrosarcoma (*Dahlin & Henderson* 1956) Non radical surgery leads to relapse and radiotherapy is without significant effect Since chondrosarcomas are most often localized in the proximal part of the femur in the pelvis or in the proximal part of the humerus surgery must be performed as disarticulation hemipelvectomy or forequarter amputation The results seem to justify such measures a 50 per cent 15 year cure rate has been reported for chondrosarcomas of the extremities (*Halelius & Hjelmstedt* 1964) and a 30 per cent 10 year cure rate after hemipelvectomy for chondrosarcoma of the pelvis (*Troup & Bickel* 1960)

While radical surgery is thus relatively successful it obviously creates new problems for the patient Hence efforts must be made to obviate the necessity of major amputations through the development of new forms of treatment which in turn may require the elaboration of new diagnostic methods However a more comprehensive knowledge of the biochemistry and metabolism of chondrosarcoma is a prerequisite condition for such attempts

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Financial support was obtained from the Swedish Medical Research Council King Gustav V 80th Birthday Fund the Knut and Alice Wallenberg Foundation and the Association for the Aid of Crippled Children New York. A preliminary account of this work was given at the Annual Meeting of the Swedish Orthopaedic Association Nov 25–27 1965 Stockholm Sweden

A characteristic feature of chondrosarcomata is the formation of an abundant matrix which as in normal cartilage contains sulfated glycosaminoglycans[1] The biosynthesis of such compounds has been studied intensively in recent years thus the various enzymes and precursors involved are known in some detail as reviewed elsewhere (*Bostrom & Roden* 1965)

From a therapeutic standpoint there are here two methods of attack First an attempt to retard the growth of a chondrosarcoma by interfering with the formation or maintenance of its matrix For instance several substances are known to have an inhibitory effect on the biosynthesis of sulfated glycosaminoglycans *viz* cortisone salicylates phenylbutazones and anti malarials (*Bostrom Berntsen & Whitehouse* 1964) Furthermore it has been shown that parenteral administration of papain can cause the breakdown of the ground substance of preformed cartilaginous matrices (*Thomas* 1956)

Second the exploitation of the pronounced anabolic activity of the tumor cells in order to introduce a precursor which when built into the sulfated glycosaminoglycans would cause damage to these cells This approach was used by *Gottschalk et al* (1959) *Gottschalk* (1960) *Andrews et al* (1960) and *Botstein & Marcus* (1963) who administered S^{35} sulfate to patients with advanced chondrosarcoma for internal irradiation of the tumor tissue The radio isotope was given in amounts of 0 6–1 2 C With this dosage temporary arrest of growth and relief of pain was noted in several cases That high doses of S^{35} sulfate have a definite radiotoxic effect on growing cartilage is evident from studies on rats (*Rubin et al* 1957) and on mice (*Gottschalk & Beers* 1958)

These therapeutic trials were based on tracer studies which included autoradiographs of biopsy material and demonstrated a preferential uptake of the isotope by the tumor tissue It was also established that the limiting factor in the therapeutic use of S is the radiosensitivity of the hematopoietic system Marked depression of bone marrow activity invariably followed the administration of the large doses of S^{35} employed However the marrow function was completely restored in about a month Consequently the possibility of multiple courses of S^{35} treatment for patients who respond well was suggested by *Botstein & Marcus* (1963) and is currently being explored in a case with lung metastases (*Boström et al* unpublished observations)

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[1] In this paper we have adopted the nomenclature used in The Amino Sugars (eds E A Balazs & R W Jeanloz Academic Press New York 1965)

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Figure 1 Case 1 Roentgenogram showing chondro sarcoma in the proximal part of the left femur



Figure 2 Case 2 Roentgenogram showing chondro sarcoma of the proximal part of the left humerus extending into the soft parts of the axilla

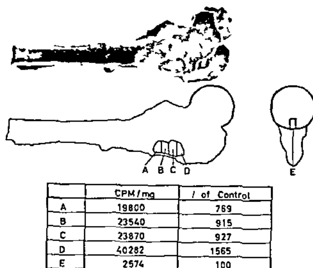
Sampling of Tumor Tissue

Each long bone was sawed in two longitudinally and the cut surfaces photo graphed One half of each bone was used for histologic diagnosis and radioisotope studies respectively For these studies tissue blocks were cut from the tumors *in situ* The blocks measured approximately 5 × 5 × 5 mm and were taken from macro scopically different areas of the tumors as indicated in Figures 3 and 4

From the tumor in case 1 four blocks were taken designated A-D in case 2 three blocks were sampled (A C) For control blocks of articular cartilage were also taken from each bone and were marked E and D respectively

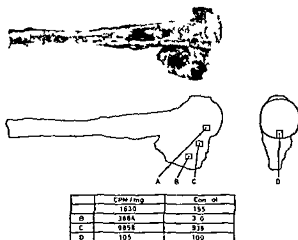
Incubation

Before incubation each tissue block was cut into two parts one for biochemical investigation and the other for autoradiography Each of these parts was subdivided into slices approximately 0 5 mm which were incubated for two hours in 5 ml of a Krebs Ringer solution containing 100 μC of radioacti e sulfate After incubation the process was stopped by addition of 1 ml of 2 per cent monoiodoacetic acid The slices were then carefully washed with water and excess of unlabelled sodium sulfate according to *Bostrom et al* (1955)



	CPM/mg	% of Control
A	19800	769
B	23540	915
C	23870	927
D	40282	1565
E	2574	100

Figure 3 Case 1 Incorporation of S^{35} sulfate (total glycosaminoglycan fraction) into various zones of the tumor (A–D) and into normal joint cartilage (E = control) Radioactivity expressed as counts per minute per mg dry tissue



	CPM/mg	Con ol
	1630	155
B	3664	3 0
C	9858	938
D	105	100

Figure 4 Case 2 Incorporation of S^{35} sulfate (total glycosaminoglycan fraction) into various zones of the tumor (A–C) and into normal joint cartilage (D = control) Radioactivity expressed as counts per minute per mg dry tissue

Biochemical Analyses and Radio Assays

The slices for examination were further washed in alcohol and ether and dried in vacuo weighed on a Cahn micro balance and digested with papain Complete solubilization of the material was obtained

From all the digested samples aliquots were taken for indirect determination of

S35 sulfate incorporation into the total glycosaminoglycan fraction The radioactivity of the aliquots was measured before and after precipitation with ethanol and subsequent centrifugation the difference between the two measurements was regarded as representing the S35 activity of the total glycosaminoglycan fraction

The digested samples from case 1 were utilized also to evaluate the incorporation of the isotope into individual glycosaminoglycan fractions These were obtained by the micro separation technique of *Antonopoulos et al* (1963) the radioactivity of each resulting fraction was measured

Assays of S35 activity were made on material plated at infinite thinness A Geiger Muller counter with a 1 9 mg/cm end window tube was used Radioactivity was expressed as counts per minute per mg of dry tissue

Morphology and Autoradiography

The incubated and washed slices were fixed in alcoholformalin (3 + 1 parts) and embedded in paraffin Semi serial sections were cut at 2 and 4 microns and mounted on glass slides About half the number of slides were used for staining and the others for autoradiography The following staining procedures were applied hematoxylin and eosin astrablau (*Bloom & Kelly* 1960) and toluidine blue (0 1 per cent in 70 per cent ethanol)

Coated autoradiograms were prepared by a modification of the *Messier & Leblond* method (1957) Ilford K5 nuclear emulsion was used diluted with either one part of water (4 micron sections) or four parts of water (2 micron sections) Exposures lasted from one to two days The autoradiograms were developed in Kodak D 19b cover slipped and were examined by light and by phase-contrast microscopy with qualitative evaluation of density Quantification through grain counting was not attempted since the autoradiograms were too dense over the cells for this in spite of the short exposure time a rather high S35 dosage being used for the *in vitro* incubations to ensure an adequate level of activity for the C M counting particularly in the fractionation study

RESULTS

Biochemical analyses and radio-assays

Figures 3 and 4 show the incorporation of radioactive sulfate into the total glycosaminoglycan fraction of the various zones of the tumors and adjacent joint cartilage These figures indicate that the uptake of S35 sulfate was much higher in all tumor samples than in the corresponding samples of normal cartilage but that there were also considerable variations between the samples of an individual tumor Thus the radioactivity of the tumor samples exceeded that of the control cartilage by a factor of about 7 to 15 times in case 1 and of about 1 5 to 9 times in case 2

The results of the fractionation study made in case 1 are summarized in Figure 5 The variation in total radioactivity between the different

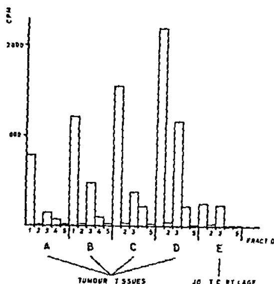


Figure 5 Case 1 Radioactivity in various glycosaminoglycan fractions in tumor tissue (A–D) and into normal joint cartilage (E) Fraction 1 keratan sulfate fraction 2 hyaluronic acid fractions 3 and 4 chondroitin sulfates fraction 5 heparin like compounds

samples essentially parallels that shown in Figure 3 All the tumor samples show a similar distribution pattern of radioactivity between the five fractions This pattern is distinctly different from that of normal joint cartilage owing mainly to a predominance by a factor of two to five in the radioactivity of fraction 1 over that of fraction 3 but also to the occurrence of significant radioactivity in fraction 4

Morphology and autoradiography

The histologic examination of the tumors showed that both were rather highly differentiated chondrosarcomas However their appearance varied markedly from area to area in respect of both cellularity and character of the matrix For instance zones with abundant matrix alternated with clusters of cells (Figure 6 A) The matrix was collagenous in some parts of the tumors and myxomatous in other parts Formation of chondroid tissue was noted in case 2 (Figure 7 A) Necrotic areas were occasionally observed

A direct relationship was readily evident between microscopic appearance and uptake of S^{35} sulfate by the tumor samples as determined by G-M counting The more cellular and the more active the appearance

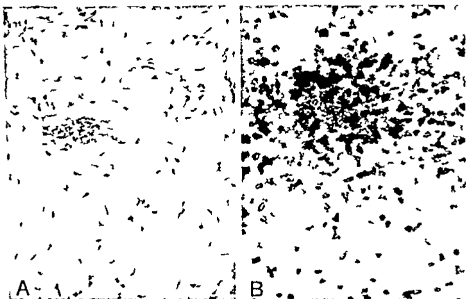


Figure 6 Case 1 A section of the tumor stained with hematoxylin and eosin B coated autoradiogram showing the incorporation of S^{35} sulfate into a similar area of the tumor × 95

of the sample the higher was its radioactivity Of the two tumors that in case 1 had the more malignant appearance and showed the most pronounced uptake of the isotope

This correlation between morphology and isotope incorporation was directly visible in the autoradiograms These show that in both tumor tissue and control cartilage the uptake of S^{35} sulfate took place as a massive cellular incorporation (Figures 6B 7B and 8) No uptake of the isotope occurred in necrotic tumor areas

In the samples of joint cartilage there was no indication of a secretion of S^{35} labelled matrix components by the chondrocytes However in the tumor samples notably within the cell clusters in case 1 rather dense accumulations of silver grains were also located over the matrix between or immediately surrounding the cells (Figure 6B)

DISCUSSION

An increased *in vitro* uptake of radioactive sulfate into the total glycosaminoglycan fraction by the chondrosarcomatous tissues as compared with the uptake of the normal joint cartilage was demonstrated in this



Figure 7 Case 2 A section of the tumor stained with hematoxylin and eosin B coated autoradiogram showing the incorporation of S^{35} sulfate into a similar area of the tumor × *95*

investigation This is in good agreement with earlier observations *in vitro* (*Layton* 1949 *Wolfe & Vickery* 1964) and *in vivo* (*Gottschalk et al* 1952 1959 *Gottschalk* 1960 *Andrews et al* 1960 *Botstein & Marcus* 1963)

The greater cellularity of the tumor tissues is a major factor affecting this increased uptake as indicated by the morphologic and autoradiographic findings Moreover the variations in radioactivity between the different tumor samples were clearly related to cellular content Conceivably an accelerated turnover may also be involved but this could not be demonstrated with certainty in the present material Variations in synthetic rate among skeletal cells can in general be detected by autoradiography namely through evaluation preferably by grain counting of the initial incorporation of the isotope into the cells or through observation of the subsequent transfer rate of labelled components to the matrix (see for instance *Öberg* 1964) The latter procedure requires the harvesting of samples after consecutive time intervals which was not possible in this study because of the limited amount of material available it has already been mentioned that grain counting was not feasible Nonetheless the occurrence of silver grains

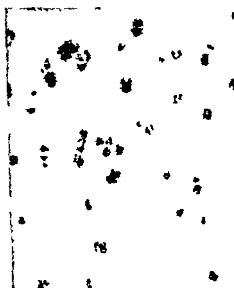


Figure 8 Case 1 Coated autoradiogram showing the incorporation of S35 sulfate into normal joint cartilage × 95

over tumor matrix may be taken as indicating increased synthetic rate compared with that of normal cartilage These silver deposits may be interpreted as representing a secretion of labelled glycosaminoglycans into the intercellular compartment and/or a more intense emission from the cells

As far as we are aware no systematic attempt has been made to characterize the glycosaminoglycans in a comprehensive material of chondrosarcomatous tumors However the occurrence of sulfated glycosaminoglycans has been examined in a few separate cases Two chondrosarcomata and one chordoma were studied by *Meyer et al* (1956) One chondrosarcoma yielded chondroitin 4 sulfate as the only glycosaminoglycan whereas the other two tumors contained only chondroitin 6 sulfate *Adams* (1963) isolated chondroitin-4 sulfate from one chondrosarcoma and demonstrated the absence of keratan sulfate Previous investigations have thus repeatedly shown that chondroitin sulfates occur in chondrosarcomatous tissue but have failed to disclose the presence of keratan sulfate It nevertheless seems reasonable to expect also the latter glycosaminoglycan to occur at least in some cases of chondrosarcoma since it too is an important constituent of normal human cartilage This assumption is supported by the results of the fractionation study in case 1

In the latter study the tumor samples showed much the same pattern of radioactivity This indicates that the malignant cells produced a

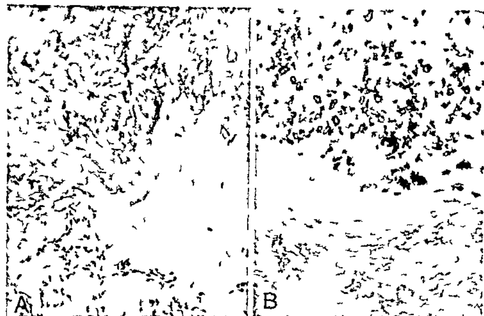


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SUMMARY

The *in vitro* incorporation of S^{35} sulfate was studied in samples from two surgically removed chondrosarcomas of long bones. Samples of adjacent joint cartilage served as controls.

The utilization of the isotope was determined by biochemical analyses made visible by autoradiography and correlated to the morphology of the individual samples.

Incorporation by the tumor samples of S^{35} sulfate into the total glycosaminoglycan fraction exceeded that of the controls by 7 to 15 times in case 1, and by 1.5 to 9 times in case 2.

Determination of the radioactivity of individual glycosaminoglycan fractions in case 1 showed that a similar spectrum of sulfated glycosaminoglycans was produced in all the tumor samples. Keratan sulfate and chondroitin sulfate(s) were the main constituents. The synthesis of keratan sulfate was greatly accelerated in relation to that of chondroitin sulfate(s).

The autoradiograms showed that the uptake of S^{35} sulfate was due to a pronounced cellular incorporation, both in chondrosarcomatous tissues and in normal cartilage. Variations in cellular content of the tissues was a major factor in causing the differences in the uptake of the isotope between the tumor samples and the control samples and also between individual tumor samples.

The significance is discussed of *in vitro* experiments as a supplement to therapeutic trials with S^{35} sulfate in cases of chondrosarcoma.

RÉSUMÉ

L'incorporation in vitro de sulfate S^{35} a été étudiée sur des prélèvements de deux chondrosarcomes d'os long obtenus chirurgicalement. Des spécimens de cartilage articulaire adjacent ont servi de contrôle.

L'utilisation de l'isotope a été déterminée par analyse biochimique rendue visible par autoradiographie et en corrélation avec la morphologie des prélèvements individuels.

L'incorporation dans les prélèvements de la tumeur de sulfate S^{35} a été effectuée jusqu'à ce que la fraction de glycosaminoglycan dépasse celle des spécimens de contrôle de 7 à 15 fois dans le cas 1 et de 1.5 à 9 fois dans le cas 2.

La détermination de la radioactivité des fractions glycosaminoglycan individuelles dans le cas 1 montre qu'un spectre similaire de glycosaminoglycan sulfate s'est produit dans tous les prélèvements de la

tumeur. Des sulfates de kératine ont été les principaux constituants. La synthèse du sulfate de kératine était fortement accélérée par rapport à celle du sulfate de chondroitine.

Les autoradiographies montrent que l'absorption de sulfate S^{35} est due à une incorporation cellulaire prononcée tant dans les tissus chondrosarcomateux que dans le cartilage normal. Des variations dans le contenu cellulaire des tissue a été un facteur majeur comme cause des variations dans l'absorption de l'isotope entre les différents prélèvements de la tumeur.

Il est discuté de l'importance des expériences *in vitro* comme complément aux essais thérapeutiques avec le sulfate S^{3} dans le cas de chondrosarcome.

ZUSAMMENFASSUNG

Die in vitro Einverleibung von S^{3} Sulfat wurde in Proben von zwei chirurgisch entfernten Chondrosarkomen langer Röhrenknochen studiert. Proben von angrenzendem Gelenksknorpel dienten als Kontrollen.

Die Ausnutzung der Isotopen wurde mittels biochemischer Analysen bestimmt, wurde mittels Autoradiographie sichtbar gemacht und in Beziehung zur Morphologie der einzelnen Proben gebracht.

Aufnahme in die Tumorproben von S^{35} Sulfat in die gesamte Glycosaminoglycan Fraktion überstieg die der Kontrollen 7 bis 15 mal im 1. Falle und 1.5 bis 9 mal im 2. Falle.

Bestimmung der Radioaktivität von einzelnen Glycosaminoglycan-Fraktionen in Fall 1 zeigte, dass ein gleichartiges Spektrum von Sulfat-Glycosaminoglycanen in allen Tumorproben erzeugt wurde. Keratinsulfat und Chondroitinsulfat(e) waren die Hauptbestandteile. Die Synthese von Keratansulfat war im Verhältnis zu der des Chondroitinsulfat(e) sehr beschleunigt.

Die Autoradiogramme zeigten, dass die Aufnahme von S^{3} Sulfat einer ausgesprochenen zellularen Einverleibung zuzusprechen war, sowohl in chondrosarkomatosem Gewebe als auch in normalem Knorpel. Unterschiede im Zellgehalt der Gewebe waren ein grösserer Faktor bei der Verursachung der Verschiedenheiten in der Aufnahme der Isotopen zwischen den Tumorproben und den Kontrollproben und auch zwischen den einzelnen Tumorproben.

Die Bedeutung der *in vitro* Versuche als eine Ergänzung zu den Behandlungsversuchen *mit* S^{35} Sulfat *in* Fällen von Chondrosarkom wird besprochen.

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A CASE OF TRAUMATIC MYOSITIS OSSIFICANS IN THE ILIOPSOAS MUSCLE

By

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Received 19 i 67

Traumatic myositis ossificans is a rare disease and it is very unusual for it to affect the iliopsoas muscle In the case to be reported below it resulted in very annoying limitation of movement in the hip

CASE REPORT

A woman aged 43 with no major illnessess injured her hand in a lawn mower Nine days later she developed tetanus and was kept under anaesthesia for 25 days After the anaesthesia she woke up with a painful left hip in which the move ments were highly restricted The complaints due to the hip prevented her from sitting normally made it difficult to dress hardly allowed a normal sex life and at last resulted in a serious depression

At the end of about 3 months she was admitted to the Department of Physical Medicine T University Hospital Copenhagen There was some atrophy of the left thigh and gluteal region The left hip was contracted in 20 flexion and 30 external rotation and it was doubtful whether the joint permitted any movement at all Attempts at moving the joint gave rise to pain and the patient felt pain when sitting and when walking which she could do however without a limp Deep to the inguinal ligament palpation revealed a firm tender ill defined area X rays demonstrated a calcific shadow 10 cm in length from the neck of the femur towards the lesser trochanter The calcific shadow was about 1 cm from the bone (cf Figure 1)

The patient was referred for orthopaedic examination which also indicated myositis ossificans in the lower part of the iliopsoas muscle The orthopaedists advised against removal of the ossified area stating that empirically its removal often gives rise to further ossification The patient was treated for a few weeks with exercises and was given a few injections of corticosteroids with local anaes thetic added She was discharged and seen in the out patient department 1 month later The condition of the hip was unchanged and so was her mental depression She wa advised to consult John Charnley chief orthopaedist in a centre for hip surgery at the Wrightington Ho pital in England Three months later Mr Charn



ley wrote that he had removed a localized mass of tissue affected with myositis ossificans and that 4 days after the operation there was almost free mobility of the left hip The patient was invited for a follow up examination here about 7 months after operation She has no subjective complaints fr m the left hip and apart from an about 20 restriction of flexion there was free mobility without pain In the sitting position the patient cannot lift her extended left leg indicating a considerably impaired function of the iliopsoas muscle (Ludloff's symptom) However this weakness of the hip flexors on the left is negligible compared with the complaints prior to the operation X rays showed that the calcific strand anterior to the femoral neck has disappeared while at the lesser trochanter there was a bean sized calcification (Figure 2)

DISCUSSION

The present case represents a rare localization of traumatic myositis ossificans which more often affects the brachial muscle the quadriceps femoris or the adductor femoris muscles (*Bailey & Love* 1946 *Croh* 1962) However a similar case has been published by *Aberle Horstenegg* (1931) A 35 year old woman overstretched her hip in a fall (into the splits) She developed a large calcified haematoma in the iliopsoas muscle on the anterior aspect of the hip joint As this caused considerable limitation of movement it was removed 6 months later with a good functional result

In respect to the treatment of traumatic myositis ossificans *Watson Jones* (1955) feels that surgery is not indicated until the haematoma around the ossification has been absorbed and spontaneous improvement of mobility in the joint no longer occurs *Bailey & Love* (1946) and *Bertelsen* (1959) state that excision to healthy tissue chiselling off inhibitory bony tissue may be required but that this should not be done until the process has become quiescent

SUMMARY

A case of traumatic myositis ossificans affecting the iliopsoas muscle is reported

This lesion caused an extremely annoying limitation of movement in one hip There is a certain tradition for reserve in applying surgical treatment although several textbooks of general and orthopaedic surgery do emphasize that it is indicated by disabling limitation of movement

Our patient underwent operation in a centre for hip surgery in England and obtained an excellent functional result

RESUME

Etude d une observation de myosite ossifiante traumatique localisee dans le muscle iliopsoas La maladie a entraine une reduction genante de la mobilite de l une des hanches Traditionellement c est avec une certaine prudence qu on a recours a la therapie operatoire dans les cas de myosite ossifiante bien que plusieurs manuels de chirurgie et d orthopedie soulignent comme indication d une intervention une reduction invalidisante de la mobilite provoquee par cette maladie

Notre malade a ete operee dans un centre de chirurgie de la hanche en Angleterre avec un excellent resultat fonctionnel

ZUSAMMENFASSUNG

Eine Krankengeschichte mit einer Myositis ossificans die im m ileopsoas lokalisiert war wird durchgegangen Das Leiden fuhrte zu einer ausserst genierenden Bewegungseinschrankung in einer Hüfte Es besteht eine gewisse traditionelle Zuruckhaltung in der operativen Behandlung der Myositis ossificans obwohl mehrere kirurgische und orthopadische Lehrbucher die Indikation dafür bei invalidisierender Bewegungseinschrankung als eine Folge des Leidens hervorheben

Unser Patient wurde an einem Zentrum für Hufteechirurgie in England mit ausgezeichnetem funktionellen Resultat operiert

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From the Orthopaedic Clinic Härnösand Sweden
(Head N Lindström MD)

THE EPIPHYSEAL ANGLE IN COXA VARA INFANTUM AND ITS RELATION TO RESULTS

By

STEFÁN HARALDSSON

Received 25 iv 67

Though the primary cause of coxa vara infantum is still obscure its roentgenological appearance is fairly well defined

There is general agreement that adequate therapy consists of various types of correction osteotomies

The purpose of the operation is above all to re establish pelvic stability and though a certain discrepancy has been described between functional and roentgenological results (*Johanning* 1951 *Magnusson* 1954) attempts are always made to obtain a correct roentgenological result *Pylkkanen* (1960) found that a good roentgenological result invariably meant a good clinical result as well

As known the pathologic anatomy is believed to consist of a disorder of the enchondral ossification of the epiphysis of the femoral head which owing to decreased strength of the juxta epiphyseal bone of the neck results in a statically induced coxa vara and sometimes even in loss of continuity in the collum

It would therefore appear that purely mechanical and dynamic factors play an important role both in the development of the deformities *and in the end results of operation*

In 1935 *Pauwels* published his first work on the effect of the slope of the fracture and thereby of the ratio between the shearing force and the force of compression on the prognosis of collum femoris fractures —It is tempting to assume that in coxa vara infantum similar mechanical factors are at work and that the angle between the pathological growth zone and the horizontal plane the epiphyseal angle may thus be of importance *in the development of the secondary varus*

Since 1932 as many as 59 growing hips with coxa vara infantum

have been treated with sub- or intertrochanteric osteotomy at the orthopaedic department in Härnosand. In 50 of these hips the roentgen films allowed measurement of the angle achieved by operation between the epiphyseal line in the caput femoris and the horizontal plane through the Y cartilage —the epiphyseal angle. This measurement (previously used by *Johanning* 1952, *Jerre* 1956, *Pylkkanen* 1960) was made in roentgenograms taken with the patient supine on the table with the lower extremities extended in neutral position. The collum diaphyseal angle was also measured in films taken at the last roentgen follow-up. This angle was measured according to *Muller* (1957).

The results of these measurements are given in Table 1.

At the time of the operation these patients were on the average 8.6 years old. The mean period of observation was 5 years.—There were 26 female and 24 male hips.

It is clear from Table 1 that all the hips with an epiphyseal angle of less than 30° at the post-operative roentgen examination showed a collum diaphyseal angle lying within the normal range at the last roentgen follow-up.

Pauwels (1935, 1965) showed that when a fracture line in the femoral neck forms an angle of more than 25° with the horizontal plane the shearing force begins to make itself felt, while when the angle is smaller the force of functional compression is predominant. The hips in Table 1 with a smaller epiphyseal angle than 30° would thus correspond to Pauwels' group 1.

Of the hips which postoperatively showed an epiphyseal angle between 30° and 50° and thus corresponded to Pauwels' group 2, 10 showed a normal diaphyseal angle at the last roentgen control, while 7 showed coxa vara (Table 1).

Table 1. Coxa vara infantum. 50 hips treated by sub- or intertrochanteric osteotomy. Roentgenological findings

Post-operative epiphyseal angle	Collum diaphyseal (C–d) angle at review. Number of hips	
	C–d angle normal (115–140°)	Coxa vara (C–d angle < 115°)
< 30°	11	
30–50°	10	7
> 50°		22

Angle between epiphyseal line and horizontal plane.

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Since 1932 as many as 59 growing hips with coxa vara infantum

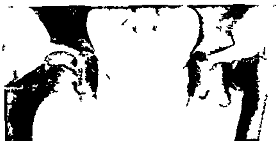


Figure 2 Case 27 ♂ Age 8 years



Figure 3 Case 27 ♂ Age 12 years

Figure 3 shows the same patient 4 years later (7 years after first examination). The right collum diaphyseal angle is 127° and the epiphyseal angle 20°, i.e. both normal.—Intertrochanteric osteotomy had been done 4 years previously on the left side. Here the collum diaphyseal angle is 88°, thus coxa vara. The postoperative epiphyseal angle of this hip was 65°.

In view of the advancing physiological varization of the collum diaphyseal angle, which occurs during the entire period of growth, the amount of spontaneous valgization shown in Figures 1 and 2 was in reality larger than what is suggested by the illustrations.

Spontaneous normalization of coxa vara infantum has been reported earlier, but judging from the literature it is rare. *Lindemann* (1949) reported 2 hips with normalization of the collum diaphyseal angle after conservative treatment. *Jerre* (1956) and *Rutt* (1957) described 1 hip each with practically complete restitution without treatment. *Pylkkänen* (1960) reported 4 untreated hips with complete spontaneous recovery.

The investigation appears to justify the conclusion that in coxa vara infantum one should not accept a postoperative epiphyseal angle of

more than 30 This conclusion is in agreement with the findings of previous workers in this field (*Johanning* 1951) Though early osteotomy is the standard therapeutic measure a certain expectative attitude might be adopted in those cases (possibly with attempted valgization by great trochanter epiphyseodesis (*Laurent* 1959 *Pylkkänen* 1960 *Chigot & Labbe* 1962)) where the epiphyseal angle does not exceed 30 and the roentgenologic juxta epiphyseal pathologic changes are moderate

SUMMARY

In a series consisting of 50 growing hips with coxa vara infantum the relation was studied between the postoperative epiphyseal angle and the collum diaphyseal angle at the last roentgen follow up

All the hips that showed an epiphyseal angle of less than 30° after the operation had a normal collum diaphyseal angle at the last re examination The larger the postoperative epiphyseal angle the greater *the tendency to coxa vara as an end result*

All the hips with a postoperative epiphyseal angle of more than 50 had a collum diaphyseal angle of less than 115° at the last re examination

The material also included 5 conservatively treated hips 4 of them showed an epiphyseal angle of about 30 all became normal spontaneously The 5th with an epiphyseal angle of 50 showed an increased varus deformity at the last examination

RÉSUMÉ

Dans une série d observations comprenant 50 hanches avec coxa vara infantum en croissance la relation entre l angle épiphysaire post opératoire et l angle colonne diaphyse au dernier examen radiographique a été étudiée

Toutes les hanches dans lesquelles l angle épiphysaire était inférieur à 30 après l opération avaient un angle colonne diaphyse normal au dernier examen Plus l angle épiphysaire post opératoire est grand plus il en résulte une tendance au coxa vara

Toutes les hanches ayant un angle épiphysaire post-opératoire de plus de 50 avaient un angle colonne diaphyse de moins de 115 au dernier examen

Les observations comprenaient aussi 5 hanches soumises à un traitement conservateur Chez 4 d entre elles l angle épiphysaire était d environ 30 Toutes devinrent normales spontanément Dans le 5ème cas

ou l'angle epiphysaire etait de 50 on a constate au dernier examen une deformite varus plus prononcee

ZUSAMMENFASSUNG

In einer Reihe von 50 Hüften im Wachstumsalter mit Coxa vara infantum wurde die Beziehung zwischen dem postoperativen Epiphysenwinkel und dem Collum Diaphysenwinkel bei der letzten Röntgennachuntersuchung studiert

Alle Huften die einen Epiphysenwinkel von weniger als 30 nach der Operation zeigten hatten einen normalen Collum Diaphysenwinkel bei der letzten Nachuntersuchung Je grösser der postoperative Epiphysenwinkel war desto grosser war die Neigung zur Coxa vara als ein Endergebnis

Alle Huften mit einem postoperativen Epiphysenwinkel von mehr als 50 hatten einem Collum Diaphysenwinkel von weniger als 115 bei der letzten Nachuntersuchung

Im Material waren auch 5 konservativ behandelte Hüften inbegriffen 4 derselben zeigten einen Epiphysenwinkel von ungefahr 30 alle wurden von selbst normal Die funfte mit einem Epiphysenwinkel von 50 zeigte eine zunehmende Varusdeformitet bei der letzten Untersuchung

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ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION BY A VASCULARIZED AND INNERVATED GRAFT

An Experimental Study on Rabbits

By

KAUKO A SOLONEN LARS HJELT & TORBJÖRN RINNE

Received 22 IV 67

For the reconstruction of the anterior cruciate ligament distally based fascia or tendon grafts (*Hey Groves* 1917 1920 *Merle d Aubigne* (according to *Ficat* 1962) *O Donoghue* 1963 *Jones* 1963) proximally attached tendon grafts (*Lindemann* 1944 *Augustine* 1954) and even the meniscus (*Smillie* 1962) are used Since it is obvious that distally based transplants have lost their blood supply and innervation it may be assumed that they are of no more value than free transplants On the other hand dynamic ligaments connected with muscle and formed by means of tendon transposition are unphysiological owing to their muscular function

In the present experimental study we have worked with tendon grafts in which neurovascular element is preserved but the muscular connexion is severed our aim being to see how such a graft behaves when it is transposed intra articularly to the site of the anterior cruciate ligament

METHOD

The experimental animals were white rabbits of the same stock and approximately the same age and weight (about 2½ kg) For the study 30 animals were used 7 of which were lost at operation or because of postoperative infection The rabbits were anaesthetized with intravenously adminstered Nembutal® (Abbott) Through an anterolateral incision in the left knee the joint was opened and the anterior cruciate ligament removed The tendon of the semitendinosus muscle was separated from the medial condyle of the tibia and the tendon was tagged with a suture The origin of the same muscle was separated with a knife from the ischial tuberosity (Figure 1) The purpose was to preserve the circulation and innervation of the muscle tendon

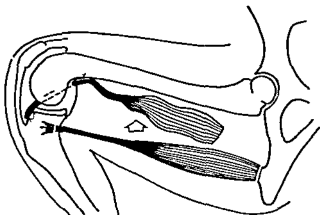


Figure 1 Operation The semitendinosus muscle is freed at both ends The tendon is transposed behind the femur and brought into the knee joint to the site of the excised anterior cruciate ligament

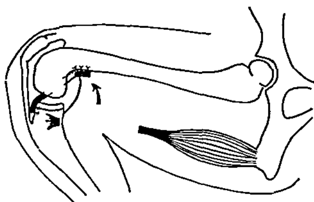


Figure 2 A free graft is taken from the tendon of semitendinosus muscle and fixed to the site of the excised cruciate ligament

unit intact. The posterior capsule of the knee was opened at its femoral insertion and through this opening the freed tendon was pulled as atraumatically as possible through the joint. The distal end of the tendon was fastened to the tibial insertion of the anterior cruciate ligament and thence anteriorly with nylon or steel sutures In some instances the tendon was attached with superficial sutures to the posterior femoral periosteum The fate of the vascular system of the muscle was investigated by means of angiography

For control operations were made in which the same part of the tendon was transplanted as a free graft to the same site as described above but with firm sutures at both ends (Figure 2) In addition ligament construction according to Hey Groves method was carried out in 2 cases (Figure 3) The operated limb was

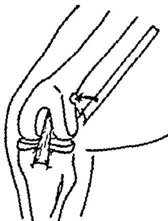


Figure 3 Hey Groves's reconstruction of the anterior cruciate ligament



Figure 4 Immobilizing plaster cast

immobilized with a plaster bandage around the trunk (Figure 4) which was removed after 3 weeks Some animals tore off the bandage earlier

The animals were sacrificed after periods of varying length Angiography of their lower limbs was carried out as follows The animal was heparinized *intra vitam* (2500 IU Heparin iv) It was then killed with an intravenous overdose of pentobarbital The abdominal aorta was exposed cannulated and injected with Micropaque suspension (1 part Micropaque/2 parts water) Perfusion was continued for 45 90 minutes at a pressure of 80 90 mm Hg An angiogram was then made of the entire hind part of the animal

The reconstructed ligament with its muscles and the corresponding ligament and the semitendinosus muscle of the contralateral limb were freed The distal ends of each ligament was marked with a suture and the freed muscle tendon units were photographed on the same plate The ligaments were placed in 10 per cent neutral formol Paraffin blocks were made in the usual way Longitudinal sections of the ligament and transverse sections of both ends and of the centre of the ligament were made The specimens were stained with haematoxylin eosin van Gieson and Gomori's trichromic staining

In all the series comprises 16 tendon reconstructions with pedicle grafts 5 tendon transplantations with free grafts and 2 fascia lata transpositions according to Hey Groves (Tables 1 3)

Table 1 Results of transposition of pedicle grafts

No	Interval between reconstruction and taking of specimen weeks	Macroscopic finding	Histological finding	Remarks
1	4½	Good	Living tendon	
2	4¾	Fair	Living tendon	Distal loosening
3	5	Good	Living tendon	
4	6	Good	Living tendon	
5	6	Poor	Infection	
6	9	Fair	Living tendon	Adhesions
7	9	Good	Living tendon	
8	10	Fair	Living tendon	Adhesions
9	10	Poor	Living tendon & degen tendon	Distal loosening
10	10	Poor	Living tendon	Adhesions, Infection
11	11	Good	Living tendon	
12	13	Good	Living tendon	
13	13	Good	Living tendon	
14	17	Good	Living tendon	
15	21	Good	Living tendon	
16	24	Good	Living tendon	

Table 2 Results of free tendon grafting

No	Interval between reconstruction and taking of specimen weeks	Macroscopic finding	Histological finding	Remarks
1	5	Good	Degeneration & necrosis	
2	6	Good	Degeneration & necrosis	
3	6	Good	Degeneration & necrosis	
4	9	Fair	Degeneration & necrosis	Adhesions
5	13	Good	Degeneration & necrosis	

Table 3 Results of Hey Groves's reconstruction

No	Interval between reconstruction and taking of specimen week	Macroscopic finding	Histological finding	Remarks
1	5½	Good	Degeneration & necrosis	
2	5½	Fair	Degeneration & necrosis	

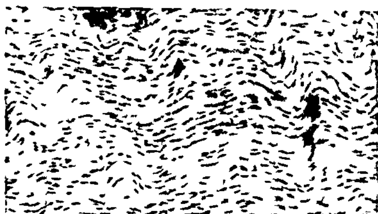


Figure 5. Normal tendon structure from a pedicle graft 9 weeks after transposition. × 120

RESULTS

Gross examination showed that the innervation of the semitendinosus muscle appears to be preserved after detachment of the muscle and transposition of the tendon.

The macroscopic intra-articular findings varied. Sometimes the interior of the knee looked normal and sometimes there was a mass of adhesions and even infection. In Tables 1–3 the macroscopic finding "good" indicates that adhesions, if any, were sparse and that the ligament appeared healthy, the knee more or less stable and the function of the limb satisfactory. "Fair" indicates some intra-articular adhesions and that the ligament is somewhat loose. "Poor" indicates abundant adhesions, infection and a ligament loosened from its site of attachment.

Evaluation of the functional result was uncertain; some animals used their leg freely, others less well.

HISTOLOGICAL FINDINGS

A. *Pedicle grafts.* In all reconstructed ligaments the structure of the tendon was normal and the graft was vital (Figure 5). In some specimens, near the distal insertion, there was waxy degeneration and scantiness of nuclei centrally. The tendon was, as a rule, vital throughout with preserved vessels in which Micropaque suspension was often seen. Whether some of these vessels came from the distal insertion or only along the tendon could not be seen. In experiments on dogs *Peacock*



Figure 6 Loss of structure and homogeni ation of a free tendon graft 9 after transpl intation × 1?0

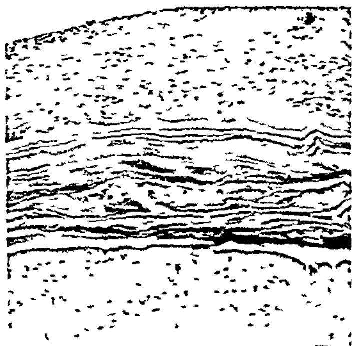


Figure 7 Necrosis of central portion of fa cia transpl int Necrosis and disin in the periphery 5½ weeks after Hey Groves s reconstruction × 1

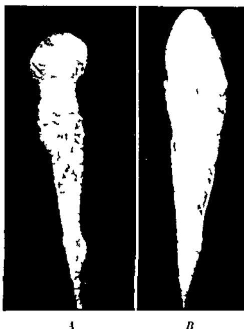


Figure 8 *Example of angiograms of transposed muscle tendon unit (A) and of the corresponding structure of the intact limb (B) (Eleven weeks after the operation)*

(1959) demonstrated that blood vessels entering long tendons from the muscular origin and periosteal insertion are able to nourish only the proximal and distal third of the tendon. The length of the tendon used in the present series is less than that of the digital flexors. From the histological specimens taken from transposed tendons it was, as a rule, impossible to conclude whether the graft had been in place for 4 or 24 weeks. When a longer period had elapsed since grafting, the synovial membrane covered the ends of the graft and sometimes even the centre of it.

B. *Free grafts* and *fascia transplants*. After transplantation with free grafts and fascia there was never a picture of a normal tendon or fascia but only of marked degeneration, disintegrating tissue and necrosis as well as inflammatory cell infiltration. Many cells were polymorphonuclear leukocytes, lymphocytes and undifferentiated cells. Neither fibroblast proliferation nor collagenization could be demonstrated with certainty. Occasionally, necroses were seen and scar tissue which replaced the necrosis without showing any tendency to form ligamental or tendon tissue (Figures 6–7). No vessels were seen in the transplants except capillaries at both insertions. Synovial membrane was seen on the surface of both ends of the transplants.

ANGIOGRAPHIC FINDINGS

Angiography was done in 13 cases A filling was always obtained of the vessels of the muscle detached at its origin or tendon (Figure 8) In none of the muscle tendon units of the intact hind legs did the blood vessels in the area of the tendon fill with contrast medium while even in the distal end of three pedicle grafts and in two cases even along the tendon a thin pattern of vessels was seen which owing to the faintness of the picture cannot be reproduced here These findings were verified in the histological specimens In none of the cases of free grafting could vascularization be demonstrated at angiography neither could this be done in the Hey Groves transplant Unfortunately microangiography proved unsuccessful

DISCUSSION AND CONCLUSIONS

When an error in the technical performance or infection did not cause complications the result of transposition with pedicle grafts *i e* intra articularly transposed grafts with preserved neurovascular elements was microscopically and histologically good However free grafts and the fascia transplants comparable with them did not remain vital The free grafts often seemed macroscopically healthy but histologically they appear to form fibrotic scar tissue only When transferred into a joint the free grafts do not become adequately vascularized from their sur roundings soon enough For the assessment of the final fate of the graft the period of observation is short As regards function the anterior cruciate ligament of the rabbit cannot be compared with that of man

SUMMARY

A preliminary investigation on reconstruction of the anterior cruciate ligament of the rabbit is described Only pedicle grafts with preserved vascularization and innervation remained vital while *degeneration* necrosis and fibrosis occurred after transplantation with free grafts or distally based fascial strips

RESUME

Une recherche préliminaire sur la reconstruction du ligament croise antérieur chez le lapin est rapportee Seules les greffes à pedicule pre servant le vascularisation et l innervation sont restees vitales alors que

la dégénération la nécrose apparaissent après transplantantion de greffes libres ou de lambeaux de fascia de bases distales

ZUSAMMENFASSUNG

Eine vorläufige Untersuchung der Wiederherstellung des lig cruciatum anterius des Kaninchens wird beschrieben Nur gestielte Transplantate mit erhaltener Gefässversorgung und Innervation erhielten sich lebens tüchtig während Degeneration und Nekrose von freien Transplantaten oder distal gestielten Fascienstreifen entstand

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FOLLOW UP EXAMINATION OF A SERIES OF ARTHRODESIS OF THE KNEE JOINT

By

P Salenius & R Kivilaakso

Received 16 i 67

When the working ability of a patient has substantially deteriorated owing to instability deformity or pain in the knee joint the possibilities of operation are few at the moment In far advanced cases arthrodesis of the knee joint is often the only means of restoring the patient s ability to work

Arthrodesis of the knee joint still has its problems As the knee joint is situated between two long lever arms complete immobilisation during the consolidation period has proved difficult to achieve (*Morris et al* 1951 *Steward et al* 1958) This is the main reason why many methods of arthrodesis have not fulfilled the hopes placed in them and have been gradually abandoned (*Brittain* 1952) In 1948 Charnley drew attention to the advantages of the compression method (*Charnley* 1948) The method bearing his name was described by Key in 1932 and has gained an ever stronger position among operative methods for arthrodesis of the knee joint (*Key* 1932 *Charnley* 1948 1958 *Morris et al* 1951 and *Steward et al* 1958)

MATERIAL

At the Orthopaedic Hospital Invalid Foundation Helsinki during the period 1946-1965 arthrodesis of the knee was performed on 106 patients of whom 59 were men and 47 women Age groups are shown in Table 1

In no case was arthrodesis performed bilaterally The youngest patient was 15 and the oldest 76 The longest observation period was 20 years and the shortest 1 year 100 patients came to the follow up examination and follow up information is lacking in respect of 6 patients only

Table 2 shows the grouping of the material according to the indication for operation

Table 1

Age	Men	Women
Below 20	6	7
20-29	16	8
30-39	15	5
40-49	11	15
50-59	8	4
60-69	3	6
Over 70	–	2
Total	59	47

Table 2

Indication	Men	Women
Tuberculosis	29	18
Polio	8	8
Arthrosis	3	12
Fract	13	3
Rheuma	–	2
Other indication	6	4
Total	59	47

The largest group was tuberculosis though the proportion of this disease has steadily decreased in recent years Among the aftereffects of polio arthrodesis was indicated by an unstable joint which hindered walking

Pain after fracture was the result of secondary osteoarthritis Seven such cases were the result of war wounds five of accidents at work and one of a traffic accident The other indication group includes the after effects of ostitis and of injury to soft tissues of the knee region where derformity or instability were indications for arthrodesis There was one case of tabes dorsalis and one of other type of neurotrophic arthropathy

METHODS

Four methods were mainly used in performing arthrodesis of the knee joint Many different surgeons were concerned so that no far reaching conclusions can be drawn as to the superiority of one method over another

By the Charnley method articular cartilage was removed in the normal way and opposing resected surfaces were pressed together with the Charnley compression device in fifty three cases The limb was immobilised in a long plaster boot for six weeks after which the compression device was removed and the boot exchanged for

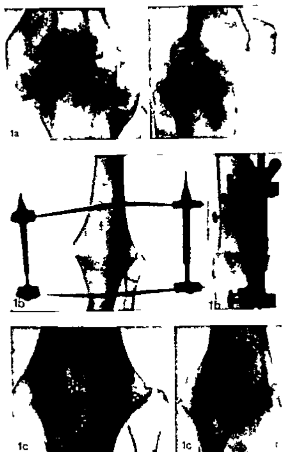


Figure 1 47 year old housewife dgn arthritis tuberculosa genus sin Patient s knee at angle of 150 after tuberculosis of knee Patient can only walk with crutches Mobility of knee 160–150 Patient also suffers from pulmonary tuberculosis A Condition before operation Anti tuberculous treatment started B Immediately after Charnley arthrodesis C Knee 6 months after Charnley arthrodesis Patient satisfied with result and walks without pain Patient again at work Anti tuberculous medical treatment continued for 2 years after operation

a plaster cylinder for 1–? months In ?0 cases the patella was embedded over the arthrodesis area (Figure 1)

For screw fixation two spongiosa screws were used These were screwed to the opposite condyle of tibia or femur in seventeen cases The limb was immobilised either in hip spica or a plaster boot at a later stage of consolidation always the latter Length of immobilisation was determined by the progress of consolidation which was checked at one month intervals both radiologically and clinically It appeared especially in cases where the screws did not reach to the cortex in the

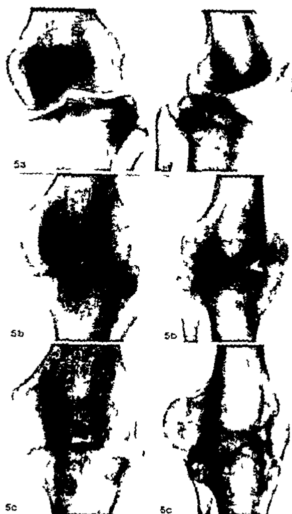


Figure 5 28 year old female furrier's assistent dgn Seq p p Paresis extr inf 1 sin Patient had poliomyelitis at age of 13 left lower limb paralysed Left knee unstable tendency to dislocation Pain A Condition before operation B Arthrodesis performed without internal fixation but with patella embedded over resection point Condition shown here is 4 months after operation when arthrodesis was considered consolidated C Condition 18 years after operation Patient entirely without discomfort Patient does light work for a living

tion though the best results were clearly achieved by the Charnley method which usually produced consolidation in less than 3 months A more exact definition of the consolidation period was not considered suitable in the present study because patients often came for post operative examination at intervals of 2–4 weeks It is evident than in

some cases consolidation occurred in a noticeably shorter time than 3 months The majority of complications and pseudarthroses appeared in cases without internal fixation On the whole patients were satisfied with the results of operation and the only cases considered as failure were those in which infection made amputation necessary Their number however was very small in relation to the total number of arthrodeses performed

SUMMARY

The authors examined 106 patients on which arthrodesis of the knee had been carried out One hundred patients arrived for follow up examination Fifty nine were men and 47 women The youngest patient was aged 15 and the oldest 76 The series includes 47 tuberculous knees 31 with osteoarthritis from fracture or other cause 16 with sequels of poliomyelitis Four methods of operation were used as follows Charnley s method—53 crosswise spongiosa screws—17 three wire coil compression—9 patients In 27 cases there was no internal metal fixation The fastest consolidation was obtained by Charnley s method 36 cases ossifying in under 3 months and 46 in under 6 months Results achieved by the various operative methods have been analysed and the aim of the follow up examination has been to elucidate the extent to which a stiffened knee has hindered a patient s working capacity

RESUME

Les auteurs ont examine les cas de 106 malades chez lesquels avait ete pratiquee une arthrodese du genou et dont une centaine se presenterent à l examen complementaire La serie d observations comprenait 59 hommes et 47 femmes Le plus jeune malade etait age de 15 ans le plus vieux de 76 ans Dans cette serie de cas il y avait 47 genoux tuberculeux 31 avec ostéoarthrite provenant d une fracture ou d une autre cause 16 ayant des séquelles de poliomyelite Quatre methodes opératoires avaient éte utilises methode de Charnley 53 fixation spongieuse transversale par vis 17 compression par enroulement de trois fils 9 Dans 27 cas il n y avait pas de fixation metallique interne La plus forte consolidation avait éte obtenue par la methode de Charnley 36 cas s étant ossifies en moins de trois mois et 46 en moins de six mois

Les resultats obtenus par ces differentes méthodes opératoires ont

etc. analyses et le but de l'examen complémentaire a été d'élucider dans quelle extension un genou raide a entravé la capacité de travail du malade.

ZUSAMMENFASSUNG

Die Verfasser untersuchten 106 Patienten, an denen eine Kniearthrodese ausgeführt worden war. Einhundert Patienten kamen zur Nachuntersuchung: 59 waren Männer und 47 Frauen. Der jüngste Patient war 15 Jahre und der älteste 76. Reihenfolge umfasst 47 tuberkulöse Kniee, 31 mit Osteoarthritis nach Bruch oder anderen Ursachen, 16 mit Folgezuständen nach Poliomyelitis. Die vier folgenden Operationsmethoden wurden verwendet: Charnleys Methode-53, gekreuzte Spongiosschrauben 17, Dreidrahtschlingenkompression 9 Patienten. In 27 Fällen wurde keine innere Metallfixation gebraucht. Die rascheste Konsolidierung wurde mit der Methode von Charnley erzielt, indem 36 Fälle unter 3 Monaten und 46 unter 6 Monaten verknöcherten.

Die mittels der verschiedenen Operationsmethoden erhaltenen Ergebnisse wurden analysiert und der Zweck der Nachuntersuchung war herauszufinden, bis zu welchem Grade ein steifes Knie die Arbeitsfähigkeit des Patienten behindert hat.

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OPERATIVE TREATMENT OF THE FOOT DEFORMITY IN CHARCOT MARIE-TOOTH DISEASE

By

STEN KARLHOLM & ULF NILSONNE

Received 13 i 68

A particular type of progressive muscular atrophy was independently described in 1886 by both Charcot Marie and Tooth It is characterized by symmetrical paresis particularly of the peroneal musculature for which reason the disease is frequently referred to as progressive peroneal muscle atrophy There may also be paresis of the anterior tibial muscle the extensor muscles of the foot and the gastrocnemius muscle The posterior tibial muscle on the other hand generally displays a normal function The imparied muscular balance results in a foot deformity consisting of an equino-varus-excavatus position As the disease spreads symmetrical paresis may also arise in the muscles of the hand and the forearms The paresis develops in a proximal direction but stops at the knee and elbow joints This centripetal progression gives the affected limbs a form that is usually likened to an upturned champagne bottle Advanced cases involve a considerable degree of invalidity—the patients can neither stand nor walk nor if the arms are affected can they perform manual work

The etiology of the Charcot Marie Tooth disease is unknown It is an hereditary complaint Two main groups have been distinguished with a somewhat different prognosis according to the age at which the symptoms first appear (*Allan* 1939) In dominant heredity the symptoms appear around the age of 30 progress slowly and lead to a moderate impairment of the function of the muscles concerned In recessive heredity the paresis appears before the age of 8 the muscular atrophy progresses rapidly and severe invalidity may have developed by the age of 15–20 years

The literature to date has chiefly been concerned with the hereditary

and neurological problems of the Charcot Marie Tooth disease Less attention has been paid to the orthopedic aspects and there has been little discussion of the possibilities for surgical correction Treatment of the foot deformity with a stabilizing subtalus arthrodesis in four cases has however been reported (*Miller* 1924)

In a large series presented more recently (*Jacobs & Carr* 1950) the surgical technique comprised lengthening of the Achilles tendon plantar fasciotomy and triarticular subtalus arthrodesis according to Lambrinudi In addition the anterior tibial tendon was transferred to the middle of the dorsum of the foot in some cases while in others the posterior tibial tendon was passed through a hole in the interosseous membrane and attached to the middle or lateral part of the dorsum of the foot Out of 44 patients (i e 88 operated feet) 32 were reported to have excellent or 'good results and the remainder poor results However those described as good included 6 cases with a recurrence of the varus deformity due to hyperactivity of the posterior tibial tendon which had been left in situ The authors regarded the subtalus arthrodesis as the most important part of the correction but emphasized that the deformity tended to recur if tendon transfer was not performed as well

OWN SURGICAL TECHNIQUE

In order to avoid bone surgery i e subtalus arthrodesis particularly in young patients the intention was to correct foot derformity by means of tendon surgery *alone The equinus position was dealt with by lengthening the Achilles tendon the* excavatus by plantar fasciotomy The varus position was countered by transferring the powerful posterior tibial tendon At the suggestion of one of us (S K) the previous technique was modified in that the posterior tibial tendon was transferred via a subcutaneous tunnel *in front of* the ankle joint and attached to the cuboid bone (Figure 1) When lengthening the Achilles tendon one must make sure that the tibial tendon can thereby reach its new insertion After the operation the foot was kept in a plaster cast for 6 weeks in an overcorrected position i e dorsal extension and pronation

CASES

This report concerns 4 patients (2 girls 2 boys) all of whom have undergone a bilateral surgical correction of typical foot deformities in Charcot Marie Tooth s disease 8 feet have thus been operating upon The age at operation varied from 5½ years to 19 years the symptoms having been present for about 3 years Heredity was confirmed for 3 of the patients the disease having afflicted both the mother the maternal grandmother and a sibling of one of them No heredity could be demonstrated in the fourth case

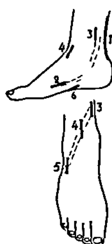


Figure 1 Incisions for the operative technique

1 *Lengthening of the Achilles tendon*
2 *Division of the insertion of the posterior tibial tendon*
3 *and 4 Subcutaneous tunnel* anterior *to the ankle joint for the posterior tibial tendon*
5 *Attachment of the posterior tibial tendon to the cuboid bone*
6 *Plantar fasciotomy*

A preliminary report on these cases has already been published (*Karlholm & Nilsonne* 1964) The average period of observation was short at that time but now ranges from 4 ½ years to 8 ½ years

RESULTS

The primary results may be described as excellent in every case Thus the transferred posterior tibial tendon functioned strongly enabling active pronation of the foot Inspection showed normal weight bearing by the feet in standing though there was possibly a slight residual excavatus position in one case Walking capacity was also more normal and ordinary shoes could be used instead of supports or special shoes

The primary improvement has been maintained throughout the period of observation in 3 cases (6 feet) (Figs 2 and 3) The stability of the feet is still good and the functional strength of the transferred posterior tibial tendon is unimpaired In the fourth case—a girl who was operated upon at 5½ years of age—there has been recurrence and deterioration The reason for this is a very marked progress of the muscular atrophy The patient now suffers from severe invalidity with almost total paralysis of the feet and lower legs as well as marked paresis in the hands and forearms The transferred posterior tibial tendon does not function actively though it does serve as a tenodesis

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larly to cases with symmetrical changes especially if the peroneal muscles are found to be weak We have not found any figures for the incidence of this disease in the literature Having had our attention drawn to the condition however we have been able to diagnose an increasing number of definite cases The complaint is perhaps not so uncommon as is stated in the usual textbooks When confronted with a case of Charcot Marie Tooth s disease one should call in the patient s closest relatives for an examination Besides providing an opportunity to analyze the hereditary pattern which may be of prognostic value this enables one to assess and treat mild or undetected deformities of the foot

Concerning the present surgical technique we wish to emphasize the particular importance of transferring the posterior tibial tendon Placing this in front of the ankle joint gives a better leverage and hence an increased power of pronation compared with the technique of passing the tendon through the interosseous membrane Moreover a subcutaneous tunnel undoubtedly provides freer passage for the tendon compared with a hole through the interosseous membrane which may lead to tenodesis On the other hand transferring the posterior tibial tendon is not sufficient by itself The equino-excavatus position must also be corrected by lengthening the Achilles tendon and plantar fasciotomy

The result of the operation was excellent in 3 cases (6 feet) and "poor in 1 case (2 feet) It is thus possible for tendon surgery alone to correct and stabilize deformities of the foot in Charcot Marie-Tooth s disease One can of course argue that equivalent results could have been achieved with a subtalus arthrodesis In our opinion however and in view of the findings of Jacobs & Carr one must nevertheless transfer the strong posterior tibial tendon in order to avoid a recurrence of the deformity We therefore conclude that bone surgery can be avoided and that tendon transfer can be sufficient

Even in the case in which the result was classified as "poor the tenodesic function produced a relative stabilization of the foot deformity The muscular atrophy was obviously highly progressive in this case The symptoms had appeared when the patient was only about 2 years old which suggest a poor prognosis and hence the indications for a tendon transfer were doubtful The result of a subtalus arthrodesis would probably not have been any better Moreover it has been shown that an early subtalus arthrodesis in congenital pes equinovarus does not produce the desired effect (*Lemperg* 1965)

SUMMARY

The typical foot deformity in the Charcot Marie Tooth disease consists of an equino varus excavatus position The deformity can be treated by soft tissue surgery alone The operative technique is described The prognosis depends not only upon the result of surgical corrections but also upon the inherent progressiveness of the muscular atrophies

RESUME

La deformite typique du pied dans la maladie Charcot Marie consiste en une position equino varus-excavatus Cette deformite peut etre traitee par la chirurgie des tissus mous uniquement La technique opératoire est décrite Le pronostic ne depend pas seulement du resultat des corrections chirurgicales mais aussi de la progression des atrophies musculaires qui s y rattachent

ZUSAMMENFASSUNG

Die typische Fussdeformitet bei der Charcot Marie Tooth Krankheit besteht in einer equino varus cavus Stellung Die Verbildung kann mittels Weichteilchirurgie allein behandelt werden Die Operations technik wird beschrieben Die Prognose ist nicht nur von dem Ergebnis der chirurgischen Korrektur sondern auch von der zugehörigen fort schreitenden Muskelatrophie abhangig

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LEG MUSCLE STRENGTH IN BELOW KNEE AMPUTEES

By

LARS BACKLUND RUDOLF LEMPERG & LARS GÖRAN OTTOSSON

Received 29 i 67

In a series of unilateral below knee amputees using a prosthesis the isometric contraction power on flexion and extension of the hip joint on the amputated side and of the hip and knee joints of the other side was studied The aim of the investigation was to study the extent to which amputation and the use of a prosthesis affected the muscle strength This is of interest in the question of whether physical capacity and mobility e g the distance which can be walked is limited by reduced muscle strength

MATERIAL

Twenty patients eighteen men and two women were selected at random from a follow up series of unilateral below knee amputees (ten right sided and ten left sided) who had used a prosthesis for at least one year The mean age was 39 4 years (range 15–58 years) The average time since the first amputation was 12 5 years (range 1–43 years) The reason for amputation was in most cases accidental injury No patients had been amputated because of circulatory disturbances None of the patients had clinical signs or a history of any other disease or injury that could limit his walking capacity

The patients were informed beforehand that the investigations were of a purely scientific nature and that the results would not be used for disability assessment.

METHODS

The muscle strength in the lower extremities was measured b four different tests These tests comprised measurement of the maximal isometric contraction power in the flexors and extensors of the hip joints and also in the flexors and extensors of the intact knee joint by methods described by *Asmussen Heeboll Nielsen & Molbech* (19 9) *Bonde Petersen* (1960) and *Asmussen & Heeboll Nielsen* (1961)

SUMMARY

The typical foot deformity in the Charcot Marie Tooth disease consists of an equino varus-excavatus position The deformity can be treated by soft tissue surgery alone The operative technique is described The prognosis depends not only upon the result of surgical corrections but also upon the inherent progressiveness of the muscular atrophies

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La deformite typique du pied dans la maladie Charcot Marie consiste en une position equino varus excavatus Cette déformité peut etre traitée par la chirurgie des tissus mous uniquement La technique opé ratoire est decrite Le pronostic ne dépend pas seulement du résultat des corrections chirurgicales mais aussi de la progression des atrophies musculaires qui s y rattachent

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Figure 1 Measurement of strength of hip flexors Healthy subject

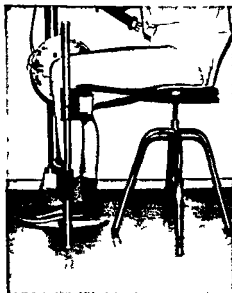


Figure 2 Measurement of strength of knee extensors left leg Healthy subject

Nielsen (1961)[1] For each patient the individual sex and the values for body height and age were taken into consideration It can be seen in the table that the mean differences between the intact and amputated side for flexion and extension were 2 per cent and 6 per cent respectively although some individual patients exhibited larger differences For the whole series however the mean value for hip flexion is distinctly lower than that reported by *Asmussen & Heeboll Nielsen*

Table 1

	Hip flexion				Hip extension			
	Intact leg		Amp leg		Intact leg		Amp leg	
	kp	%	kp	%	kp	%	kp	%
M	45	77	44	75	48	104	45	98
n	20	20	20	20	20	20	20	20
Range	20–74	38–113	21–60	36–92	21–72	51–156	22–70	50–149
S D		17 2		17 2		20 1		20 1

Table 2a Able to Walk 1 Km

	Hip flexion				Hip extension			
	Intact leg		Amp leg		Intact leg		Amp leg	
	kp	%	kp	%	kp	%	kp	%
M	46	79	44	76	49	10[illegible]	48	105
n	16	16	16	16	16	16	16	16
Range	20–74	38 113	2[illegible]–60	36–92	21–72	51–15[illegible]	31–[illegible]0	71–149

Table 2b Unable to Walk 1 Km

	Hip flexion				Hip extension			
	Intact leg		Amp leg		Intact leg		Amp leg	
	kp	%	kp	%	kp	%	kp	%
M	43	77	40	72	43	95	33	73
n	4	4	4	4	4	4	4	4
Range	3[illegible]–49	57–85	21–47	36–81	38–48	85–109	22–40	50–91

1 The tables give the standard deviations found by *Asmussen & Heeboll Nielsen* 5 patients out of the whole group showed values which were reduced by more than 2 S D with hip flexion on the intact and/or amputated side Of these 1 patient was not able to walk more than 1 km With hip extension one intact and one amputated leg (2 different patients) showed values reduced by more than 2 S D

Table 3 *Muscular Strength in Knee Flexors and Knee Extensors Intact Leg*

	Knee flexion				Knee extension			
	Right		Left		Right		Left	
	Torque Kpcm	%	Torque Kpcm	%	Torque Kpcm	%	Torque Kpcm	%
M	1 29	98	1108	89	1859	102	2006	110
n	10	10	10	10	10	10	10	10
Range	960 1650	62 121	650–1400	50–110	1120 2600	79 135	1750 2600	64 162
S D		15		15		18		18

Table 2 shows the percentage deviations from the normal values for the hip muscles when the series is divided into (a) a group of patients who stated that they could walk more than 1 km on flat ground and (b) a group of patients who stated they were unable to walk as far as 1 km In group (b) lateral differences are seen with lower values for the amputation side

Table 3 shows *the mean percentage deviation from the normal values* for the whole series on flexion and extension of the knee Here also the patients were divided into two groups in the same way as above (*Table 4*)

Table 4a Able to Walk 1 Km

	Knee flexion		Knee extension	
	Right (%)	Left (%)	Right (%)	Left (%)
M	97	92	104	105
n	9	7	9	7
Range	6[illegible]–121	62–107	79–135	64–1[illegible]

Table 4b Unable to Walk 1 Km

	Knee flexion		Knee extension	
	Right (%)	Left (%)	Right (%)	Left (%)
M	104	89	85	1[illegible]0
n	1	3	1	3
Range	104	56–110	85	108–133

Seven of the 18 male patients were also tested with bicycle ergometry *for measurement of the circulatory type of the physical work* capacity (*Sjostrand* 1960) In 5 cases with values for muscular strength within the normal range normal circulatory conditions were found (mean value for W_{130} = 700 kpm/min) One of these patients could not walk more than 1 km

In the other 2 cases a decreased physical work capacity was found (W_{130} = 400 resp 450 kpm/min) one of them had a normal and the other a somewhat *lowered muscular strength*

On knee flexion values reduced by more than 2 S D were recorded for 2 patients The distance which one of the patients could walk was < 1 km On knee extension no values were reduced below the limit of 2 S D

DISCUSSION

A large number of factors may affect the walking capacity in below-knee amputees wearing a prosthesis. One parameter is the leg muscle strength both in the intact leg and on the amputation side. This investigation has shown that as a rule there is no marked reduction of the isometric contraction power either in the intact or the amputation leg. Although the values in some individual patients fall into the lowest part of the normal range reported by *Asmussen & Heeboll Nielsen* (1961), with the method used here the group as a whole shows normal values. The general reduction observed on hip flexion may, as mentioned above, possibly to some extent be related to the fact that in this test the possibilities of fixation for the patients were poor and therefore falsely low values may have been obtained. Normal subjects may also have fixation difficulties in this test, as has been found in another study on healthy males for whom in fact almost equally low values were noted (*Bäcklund & Nordgren* 1966).

Another explanation may be that the reduction in flexion power is a true one and due to the fact that the flexors in these patients are exercised less than the extensors. The training of the hip extensors is obviously adequate, partly because of their function as antigravitational muscles and partly because of the special gait developed by persons using an artificial leg; on the other hand, their inability to run or to walk quickly would be expected to result in inadequate training of the hip flexors.

The lateral differences recorded for hip flexion (Table 1) are not abnormal. In the normal series mentioned above differences of about 2 per cent were noted both for the hip and knee joint. Differences of the same order of size have also been reported previously (*Heeboll Nielsen* 1964). On hip extension the group as a whole showed a difference with 6 per cent lower values for the amputation side. This difference was on the average negligible (2 per cent) in the patients who were able to walk 1 km, but considerable (22 per cent) in the other patients. This large lateral difference may, however, be due to chance in consideration of the fact that the number of patients who according to case history were unable to walk as far as 1 km was only 4, and that some individuals in both the other group and in the normal series showed lateral differences of the same order of size. The classification of the patients into those who were able and those who were unable to walk as far as 1 km may seem arbitrary. The borderline for a normal walk

ing capacity varies considerably e g with age but a maximal walking distance of less than 1 km is so low that it can be considered to indicate pathologically limiting factors

Difficulties in fixation also seem to have played some role in the *knee flexion* and knee extension tests Because of the test conditions the patient was placed in an eccentric position for left sided knee flexion and for right sided knee extension which probably affected the fixation of the trunk and thus may have given systematically lower values for these tests No similar results were obtained for the normal series but this difference can probably be explained by the difficulty of the amputation patients in gaining a purchase with the artificial leg

In spite of the shortcoming of the method which in some tests may have caused some systematic reduction of values in general no remarkable reduction of the leg muscle strength was shown in these unilateral below knee amputees This finding contradicts the result of *Hettinger* (1959) who observed that in such patients there was a bilateral reduction of muscle strength in the hip both in the flexors and extensors In addition he noted a lateral difference for the hip flexors with lower values on the amputation side According to our overall assessment of the patients in this series in whom the strength reductions were accompanied by a limited walking capacity these reductions should be *regarded as a result of this limitation due to other factors rather than its cause* Several of the patients with low values for muscular strength were able to walk further than 1 km and it follows therefore that decreased power in the muscle groups tested need not necessarily result in such pronounced limitation of the walking capacity

One factor which is possibly of great importance for the walking capacity in these amputation patients is the occurrence of pain Although pain of such extent as to limit the achievements of the patients did not occur in any of these tests all four patients who were unable to walk for more than 1 km complained of pain in the amputation stump on walking On the other hand such pain only occurred in 2 of 16 patients who could walk for more than 1 km It seems probable therefore that other factors especially pain on effort are of greater importance as regards the walking capacity of a patient with a below knee prosthesis than the muscular power of the legs To judge from our findings physical training would have little influence on the walking capacity in such cases However active exercises are of great clinical importance for other reasons by counteracting contractures and improving the patient s coordination and control of his prosthesis after leg amputation

SUMMARY

The maximal isometric muscle strength for flexion and extension in both hips and in the normal knee was assessed in twenty unilateral below knee amputees wearing a prosthesis for more than one year At hip flexion tests the bilateral values tended to be low However the group as a whole showed values within normal limits

In some individual patients a normal walking distance was found in spite of low muscle strength Pain in the amputation stump on walking seemed to be of grater importance as a limiting factor

RESUME

La force maximum isometrique du muscle pour flexion et extension dans les hanches et les genoux normaux a ete etablie dans 20 cas d'amputation unilaterale au dessous du genou chez des malades ayant porté une prothese pendant plus d'un an Au test de flexion de la hanche les valeurs bilaterales avaient tendance a etre basses Quoi qu'il en soit pour l'ensemble du groupe on trouva que les donnees constatées restaient dans le cadre des limites normales

ZUSAMMENFASSUNG

Die maximale isometrische Muskelkraft bei Beugung und Streckung in beiden Huften und im normalen Knie wurde bei zwanzig Personen mit einseitiger Amputation unterhalb des Kniees die eine Prothese länger als ein Jahr getragen hatten geschätzt Bei den Prufungen der Huftbeugung hatten die beiderseitigen Werte die Neigung neidrig zu sein Die Gruppe als ganzes jedoch zeigte Werte innerhalb normaler Grenzen

ACKNOWLEDGEMENT

This investigation was supported by grants from the Folksam Insurance Company Stockholm Sweden.

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A CLINICAL TRIAL WITH INDOMETHACIN (INDOMEE®) IN LOW BACK PAIN AND SCIATICA

By

IAN GOLDIE

Received 20 ii.67

INTRODUCTION

General Remarks on Inflammation and Antiinflammatory Drugs

The antiphlogistic properties of certain drugs are often claimed to be combined with an analgesic effect (*Gabka* 1964 *Sicuteri* 1964 and *Heimann* 1965) The background for this statement is the observed specific influence of the antiphlogistic agent on a particular sequence the assumed painproducing oedema in the process of inflammation Some however have a centralanalgesic effect like *e g* phenylbutazone (Butazolidin®)

The inflammatory reaction is the response of mesenchymal tissues to irritation irrespective of its origin—mechanical thermal chemical or infectious The sequence of events generally follows a well con formed pattern in which however the time factor and other tissue re actions may cause alterations so that an irregular interchange of events may ensue rather than a linear development

This unspecific tissue response contains a destructive and a repara tive phase both of which are closely interconnected The first includes haemorrhage formation of oedema local acidosis swelling and partial destruction of individual tissue components Parallel to these repara tive forces are instituted such as hyperemia exsudation of fibrin leucocytosis and phagocytosis With these events in mind it may there fore be justified to use antiphlogistic agents with specific action on the destructive phase of inflammation which do not interfere with the reparative phase Despite the assumed importance of oedema in repair

of injured tissues (*Asboe Hansen* 1963) it may be of some advantage to combat its formation as it is supposed *that inflammatory swelling* causes pain Moreover *Rhoads et al* (1942) found that in retarded wound healing in hypoproteinemia oedema had a deleterious effect on the repair of tissues

The action of antiphlogistic drugs thus becomes twofold the first being interaction in the destructive phase of inflammation and the second being analgesic in the diminishing effect on oedema

Drugs used for antiinflammatory purposes have not been sufficiently selective in their action and their overall interference in cellular metabolism has had a deleterious effect on the proliferative phase *E g* the influence of corticosteroids on exsudation of fibrin and on fibroblastic activity *which slows down the rate of healing* (*Dougherty 1954*) *is* well known *Sandberg & Steinhardt* (1964) have found that the retarding influence of steroids on wound healing depends on the inhibition of an enzyme histidinedecarboxylas With the introduction of non steroid compounds such as phenylbutazone (Butazolidin®) oxyphenbutazone (Tanderil®) and indomethacin (Indomee®) it has been proved in experimental investigations that the proliferative phase is undisturbed (*Winter* 1964 *Brunius & Zederfelt* 1965) and that the painproducing destructive phase with oedema is combated (*Winter* 1964)

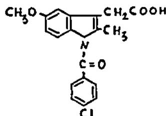
Problem

The origin of low back pain with sciatic irradiation is obscure and many explanations have been forwarded The common and most accepted cause is the pressure a herniated intervertebral disc exerts on the nerve root But mechanical factors are not the only painproducing agents and chemical degenerative and autoimmune reactions either primary or secondary to ruptures in the disc substance have to be considered (*Hirsch* 1965) They all form part of the inflammatory reaction and no doubt a nerve root can be interfered with by the sole products of an inflammatory development without the intervertebral disc material necessarily appearing as a herniation (*Hirsch 1965 Nachemson* 1965)

This study has therefore been carried out to assay the effect of—indomethacin (Indomee®)—in patients with an acute attack of sciatica

Properties of Indomethacin (Indomee®)

Indomethacin is 1 (p chlorbenzoyl) 5 methoxy 2 methyl indole 3 acetic acid It has formula of $C_{19}H_{16}NO_4CL$ and a molecular weight of 357 8



It is relatively insoluble in water but is soluble in the common organic solvents (*Shen et al* 1963) Experimental studies (*Winter* 1964) show very active antiinflammatory properties In inhibition tests on granulation tissue in rats indomethacin was 85 times more active than phenylbutazone and 4 times as active as hydrocortisone Its inhibiting action on oedema has also been recorded in animal studies and it was 30 and 20 times as active as salicylates and phenylbutazone respectively but only twice as efficient as hydrocortisone (*Winter et al* 1963)

The analgesic effect has also been tested in clinical trials (*Jacobs* 1965) and 50 mg indomethacin has the same effect as 600 mg salicylic acid (*Wanka Jones Wood & Dixon* 1964 *Percy Stephenson & Thomson* 1964)

Side effects have been reported such as headache dizziness rashes and dyspepsia In 1964 Lovgren and Allander reported several cases of peptic ulceration and haemorrhage two of which had a fatal outcome *Wanka et al* (1964) have also reported on cases with gastric bleeding and ulcers Since the drug no longer has been administered as tablets but in capsules gastric side effects have almost completely disappeared Besides these can be alleviated by taking the drug with meals

Headache is as a rule transient (*Hart & Boardman* 1963) and dependent on the dosage Hepatic renal and haematological complications have not been reported

Indomethacin was originally introduced as an antirheumatic drug As its antiphlogistic properties became more known the range of indications widened to include most conditions with pain secondary to tissue reactions of inflammatory type Thus inflammatory reactions in periarticular structures have appeared to be a good target for

treatment with indimethacin (*Jacobs* 1965) The dosage recommended is 75 mg–100 mg per day divided into three or four doses

METHOD

The trial was a blind inter patient comparison patients receiving a course of 50 capsules of either indomethacin or placebo The indomethacin was administered as capsules containing 25 mg of the drug a total of 75 mg being taken each day in three divided doses The placebo was administered in identical capsules three times daily

Neither doctor nurse or patient were aware of which treatment was given as the bottles in which the capsules were dispensed only had a number on the label the code of which was known only to the manufacturer

Only patients with true sciatica *i e* low back pain with irradiation down either leg were selected excepting six patients in whom the irradiation was not as constant but the back pain very severe The duration of symptoms did not exceed three weeks All but five patients were hospitalized and their reactions were read on day 1–5 and thereafter at weekly intervals up to at the most three months As indomethacin is said to institute its effect within 24–48 hours (*Ward* 1964) it might have been sufficient with definite readings after this time but for the sake of completeness it was felt more appropriate to carry on the observations and make a conclusive registration after 14 days

As in many cases sciatica may be a self limited disease within this time the daily registration and final observation were however thought necessary to evaluate any possible radical influence the administered drug might have

No other drugs as sedatives hypnotics or supplementary analgesics were administered No physiotherapy was given The patients as a rule remained in bed for a few days and were allowed to move around freely

The following criteria were measured initially and on subsequent registrations All observations were made by the author

Subjective evaluation of pain The patient were asked daily about the intensity of pain and the relief was registered as complete fair or none using a score system with initial pain and no recovery recorded as 3 points lessened pain = fair relief = 2 points no pain = complete relief = 1 point.

Irradiation of pain The patients were asked daily if any change in irradiation was noted in either intensity or spread

Alteration in straight leg raising test The test was performed daily The difference before and after treatment was expressed in degrees and final registration was made after 14 days

Other neurologic signs

MATERIAL

The total number of patients amounted to fifty

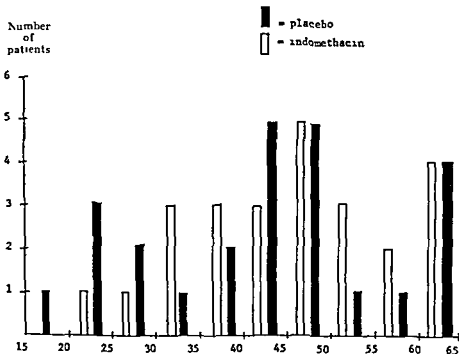
After decodification and division into indomethacin and placebogroups the distribution was as follows Table 1

The age distribution is seen in Table 2 and corresponds well with the distribution of lumbago and irradiating pain as reported elsewhere (*Hirsch* 1965)

Table 1 Distribution of patients in treatment groups after decodification

Sex	Indomethacin	Placebo
Male	13	13
Female	12	12

Table 2 Distribution of age and treatment of material



Duration of symptoms before treatment is seen in Table 3

Table 3 Duration of symptoms

Time	Indomethacin		Placebo		Total
	Male	Female	Male	Female	
One week	4	3	7	3	17
Two weeks	7	9	4	8	28
Three weeks	2	–	2	1	5

Side affected is seen in Table 4

Table 4 Localisation of pain

Sex	Lumbago ischias sin		Lumbago ischias dx		Lumbago ac	
	Indo methacin	Placebo	Indo methacin	Placebo	Indo methacin	Placebo
Male	4	8	6	4	3	1
Female	3	6	9	4	–	2
Total	7	14	15	8	3	3

Straight leg raising test before treatment in seen in Table 5

Table 5 Straight leg raising before treatment

Straight leg raising test	Indomethacin		Placebo		Total
	Male	Female	Male	Female	
Negative	7	7	6	9	29
Positive 10–40	3	1	1	1	6
Positive 40–80	3	4	6	2	15

RESULTS

It very soon became evident that decrease in pain was a slow process and that recordings would gain in reliability if measurements were made at slightly longer intervals After seven days of treatment the subjective relief of pain was as follows, see Table 6

At the conclusive registration after 14 days the evaluation of pain was as seen in Table 7

Table 6 Subjective evaluation of pain after 7 days treatment

Relief of pain	Indomethacin		Total	Placebo		Total
	Male	Female		Male	Female	
Complete	5	2	7	5	4	9
Fair	4	4	8	4	5	9
None	4	6	10	4	3	7

Table 7 Subjective evaluation of pain after 14 days treatment

Relief of pain	Indomethacin Male	Indomethacin Female	Total	Placebo Male	Placebo Female	Total
Complete	9	5	14	7	9	16
Fair	–	1	1	2	–	2
None	4	6	10	4	3	7

Of the 17 patients with no relief 3 were later operated on for a herniated disc in the indomethacin group and 2 in the placebo group These 5 patients still have complete relief of pain from 3 to 1 months after surgery

The remaining 12 who had not experienced any relief of pain after 14 days were further checked for 3 months Of these 10 had received physiotherapy and taken muscle relaxants and analgesics of various kinds 5 had complete relief of pain 3 still suffered constant but very mild pain which was alleviated by rest and light analgesics 2 still suffered from such severe pain that admission for myelography was considered

Straight Leg Raising Test

Indomethacin group After 14 days 4 were normalised 7 remained as before treatment Crossed straight leg raising pain was not observed

Placebo group Of 10 positive 3 patients were normalised In one patient crossed straight leg raising pain was present prior to the treatment After 14 days therapy it remained Those patients who were later operated for herniated disc from both groups had positive straight leg raising tests of 40 –80

Reflexes

Indomethacin group At initial examination no areflexia was registered in any case At final registration after treatment no change was noted

Placebo group At initial examination one patient responded with no reflexes at all All the remaining had normal reflexes At the conclusion of treatment the patient with areflexia still retained this She did not belong to the group in which eventually operation was performed No change in reflexes was observed in the remaining patients after treatment

Sensitivity

Indomethacin group Normal sensitivity was encountered in all but two These had reduced sensitivity for pain along the outside of the lower leg After treatment the loss of sensitivity remained They were later operated for herniated disc in the level L IV–L V The sensitivity was *not influenced by the treatment in the remaining patients of this group*

Placebo group Before treatment 5 patients had reduction of sensitivity In 3 this corresponded to the radiation of the L V root and in 2 the S I root Two of the former were operated for a herniated disc at the L IV–L V level Normal sensitivity was encountered in the remaining patients in this group before and after treatment

Big Toe Paresis

Indomethacin group Three patients had a big toe paresis before as well as after treatment Of these two were operated for herniated disc at the L IV–L V level The remaining patient had no paresis either before or after treatment

Placebo group One patient initially had a paresis which remained after treatment This patient was later operated for herniated disc at the L IV–L V level No paresis was observed in the remainder of this group

Table 8 Results of treatment on different signs

Signs	Indomethacin treatment		Placebo treatment	
	before	after	before	after
Straight leg raising				
Negative	14	18	15	18
Positive 10–40	4	1	2	1
Positive 40–80	7	6	8	6
Reflexes				
No absence	25	25	24	24
Absence	–	–	1	1
Sensitivity				
Normal	23	23	20	20
Reduced	2	2	5	5
Big too paresis				
Not present	22	22	24	24
Present	3	3	1	1

Side Effects

In 13 patients headache nausea and giddiness were observed which in all instances appeared within some 24 hours after initiation of treatment To secure that the side-effects could be ascribed to the given preparation its administration was withdrawn for a few days and then reinstituted after disappearance of the side-effects They returned in all 13 patients within 12 hours after the second course of administration The side-effects were distributed as is seen in Table 9

Table 9 Side effects of administered preparations

Side effect	Indomethacin		Total	Placebo		Total
	Male	Female		Male	Female	
Headache	–	4	4	1	1	2
Nausea	–	4	4	–	2	2
Giddiness	–	–	–	–	1	1

COMMENT

Mechanical factors no doubt have a great importance in the pathogenesis of low back pain and sciatica As mentioned above however chemical degenerative and perhaps autoimmune processes are concomitant and may augment the role of mechanical factors in the mechanism which primarily elicits pain In 1958 Olsson came to the conclusion based on thorough animal experiments that large herniations of discs need not necessarily evoke symptoms but rather that a dynamic factor is responsible for the symptomatology and that this is an exponent for an inflammatory reaction For this reason he believed that the activity of the inflammatory reaction had to be combated as a therapeutic measure more than the removal of protruding disc tissue

In a study based on observations at operation for lumbago in humans *Lindahl & Rexed* (1959) showed that a pronounced fibrosis was present around the nerve root which supplied the segment from which the symptomatology originated *Nachemson* (1966) has investigated in a double blind trial the effect of oxyphenbutazone (Tanderil®) at operation for herniated discs with special reference to various factors such as hemoglobin leukocytes thrombocytes postoperative pain and haemorrhage during operation He found that oxyphenbutazone had a significantly reducing effect on haemorrhage

With the above observations in mind it therefore appears logical to

Sensitivity

Indomethacin group Normal sensitivity was encountered in all but two These had reduced sensitivity for pain along the outside of the lower leg After treatment the loss of sensitivity remained They were later operated for herniated disc in the level L IV–L V The sensitivity was not influenced by the treatment in the remaining patients of this group

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handelt Man fandt keinen grosseren Unterschied in der Erleichterung der Schmerzen nach einer Behandlung von vierzehn Tagen Vollständige Erleichterung der Schmerzen wurde bei 14 Patienten der Indomethazingruppe und bei 16 in der Placebogruppe gefunden Kein Einfluss der Behandlung auf die Probe der Hebung des gestreckten Beines auf Reflexanomalien Verlust der Sensibilitet oder Parese des Extensor der Grosszehe konnte beobachtet werden

In dieser Untersuchung war es daher nicht moglich irgendeine deutliche Wirkung der Indomethazinbehandlung in Fallen von Lumbago oder Ischias nachzuweisen

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CORTICAL BONE IN MAN

III Variation of Compressive Strength with Age and Sex

By

OLOV LINDAHL & ÅKE G H LINDGREN

Received 15 iii 67

This is the third of a series of studies on cortical bone reports of which have been published in earlier issues of this journal (2 3)

MATERIAL

A full account of the material for this study has been given elsewhere (2) Compact cortical bone was taken from the femur and humerus of 64 autopsy subjects of various ages As the femur is slightly curved the specimens for the compression test were taken from the posterior circumference of the bone which is usually subjected to compression while the tensile tests (3) were carried out on specimens from the anterior part generally subjected to traction. From the humerus the specimens were taken where the cortical bone was thickest and yielded most material

METHODS

Storage

The specimens were stored in air at 3–5 C (3) After preparation they were kept at constant temperature and relative humidity (20 C and 65 per cent re h) until equilibrium with respect to the latter had been reached.

Test Bodies

The compressive tests were performed on test bodies 2 1–3 8 mm long removed in the axial direction of the bone by means of a facing cutter run at a low milling speed so as to avoid heating The bodies were of rectangular and uniform cross section throughout their length with the dimensions 1 3–2 0 × 2 7–3.3 mm. These dimensions were measured with a micrometer and a variation of up to 0 01 mm was accepted within any particular test body Two such bodies were made for each bone (femur or humerus) with a few exceptions where because of the small dimensions and porosity only one could be obtained.

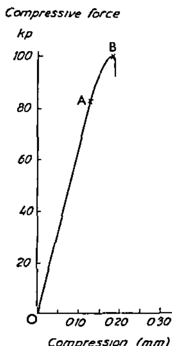


Figure 1 Force compression diagram for compression tests on a bone specimen From O to A the curve is approximately straight and the compression proportional to the applied force The stress (compressive force/cross sectional area of the body) for the bone at A is the limit of proportionality (kp/mm) The compression at rupture (B) is expressed as the percentage deformation of the original length of the body The modulus of elasticity is the ratio of stress to strain that is

$$\frac{\text{load/initial area of section}}{\text{deformation/original length}}$$

for the lineal part of the curve (O–A)

Apparatus

The test bodies were made and the compression tests carried out with an Alwetron apparatus at the National Testing Laboratory Stockholm The rate of deformation was 0 05 mm/min The deformation was recorded continuously and on the basis of the graphs so obtained the ultimate strength compression at rupture limit of proportionality and the modulus of elasticity were obtained (Figure 1)

Statistical Methods

The statistical analysis was performed with the same methods as in an ealier study (1)

RESULTS

The results are summarized in Table 1

Table 1 Means of compressive strength parameters
The values in parenthesis are ranges

	Men		Women	
	Femur (n = 30)	Humerus (n = 30)	Femur (n = 30)	Humerus (n = 19)
Ultimate strength (kp/mm²)	19.7 ± 0.3 (14.8–22.[illegible])	18.8 ± 0.4 (13.3–21.4)	18.3 ± 0.4 (12.7–2[illegible].4)	19.1 ± 0.3 (16.4–21.7)
Compression at rupture (%)	5.3 ± 0.5 (3.5–14.8)	4.5 ± 0.3 (2.8–9.6)	4.3 ± 0.2 ([illegible].8–7.[illegible])	3.9 ± 0.2 ([illegible].3–6.4)
Limit of proportionality (kp/mm²)	15.8 ± 0.4 (10.1–18.3)	16.1 ± 0.4 (10.6–19.1)	15.7 ± 0.4 (9.3–[illegible]0.5)	16.7 ± 0.3 (13.6–19.2)
Modulus of elasticity megap/mm †	1.05 ± 0.06 (0.30–1.76)	1.10 ± 0.05 (0.45–1.58)	1.07 ± 0.05 (0.46–1.55)	1.20 ± 0.07 (0.71–1.85)

1 kp/mm² = 14[illegible] lb/in² (psi)
1 megap = 1000 kp 1 kp (kgf) = 9.80665 newtons = 2.2046 lb force
1 megap/mm² = 1 4[illegible] 000 lb/in² (psi)

Compressive Strength

There was no difference in the ultimate strength between the femur and humerus The femur was significantly (   ) stronger in men than women, with a mean difference of 8.0 per cent There was a decrease in this property with age from 20 years upwards in both men and women and for both the femur and the humerus (Figure 2) The mean reduction was about 15 per cent and was significant (   )

Compression at Rupture

For all age groups and both sexes the compression at rupture was greater for the femur than for the humerus the difference was significant (   )

For the men below 40 years there was a significant (   ) reduction with age of about 40 per cent in the compression at rupture for both humerus and femur (Figure 3)

For women there was no such variation

Limit of proportionality

This property showed no difference between the sexes or between the femur and the humerus After 20 years there was a reduction of about 15 per cent with age (almost significant   ) (Figure 4)

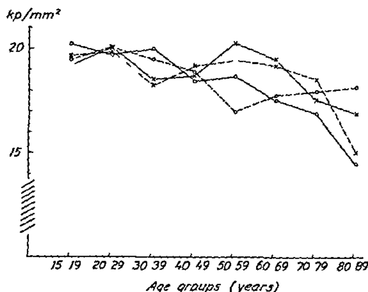


Figure 2 Mean compressive ultimate strength for the femur and humerus both sexes and various age groups Men ○ women × femur —— humerus ----

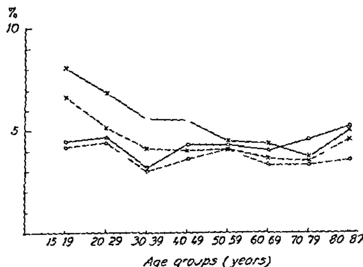


Figure 3 Mean compression at rupture for the femur and humerus both sexes and various age groups Men ○ women × femur —— humerus ----

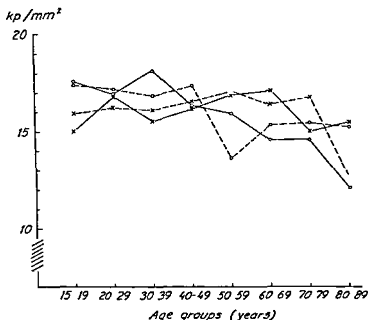


Figure 4 Mean limit of proportionality for the femur and humerus both sexes and various age groups Men ○ women × femur —— humerus ----

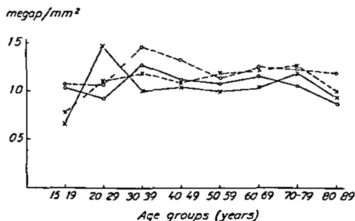


Figure 5 Mean modulus of elasticity for the femur and humerus both sexes and various age groups Men ○ women × femur —— humerus ----

Modulus of Elasticity

There was no difference between the sexes as regards the modulus of elasticity but in practically all the age groups and for each sex the value was higher for the humerus than for the femur the difference was almost significant ( ) There was no variation with age (Figure 5)

DISCUSSION

As in the case of the tensile strength the measurement of the compressive strength indicated the presence of qualitative changes in the bone with age The ultimate strength decreased by 15 per cent the compression at rupture by 40 per cent and the limit of *proportionality* by 15 per cent Whereas the humerus had a higher ultimate strength at tension the femur showed a higher compression at rupture This would seem to reflect functional adaptation the femur being subjected *to compression more than the humerus*

In contrast to the values for the tensile strength for the compression there was a small difference between the sexes the ultimate compressive strength of the femur being significantly greater for men than women It is difficult to judge whether this difference is due to a real difference between the sexes or to the composition of the material The differences between the femur and humerus have another significance since the comparisons are made on the same subjects

As in the case of the tensile strength the compressive strength showed extremely large individual variations The means are in close agreement with those reported in the literature

SUMMARY

A study has been made of compressive strength compression at rupture limit of proportionality and modulus of elasticity of cortical bone of the femur and humerus The specimens were obtained from autopsy subjects of both sexes and a wide range of ages There was a qualitative change in the cortical bone with age reflected in a reduction in all the properties except the modulus of elasticity

RESUME

Il a été procédé a une étude sur la force de compression la compression a la rupture la limite de la proportionnalité et le module d elasticité de

l os cortical du femur et de l humerus Les specimens ont ete preleves a l autopsie de sujets des deux sexes representant une gamme d ages varies On a observe des modifications qualitatives de l os cortical avec l age refletant une reduction de toutes les proprietes excepte le module de l elasticit

ZUSAMMENFASSUNG

Ein Studie der Kompressionsstarke der Kompression bei der Spreng ung der Grenze der Proportionalitet und des Modulus der Elastizitet von kortikalem Knochen des Femurs und Humerus wurde ausgefuhrt Die Proben wurden von Autopsiesubjekten beiderlei Geschlechtes und weit verschiedenen Altersklassen erhalten Man fandt eine qualitative Veränderung des kortikalen Knochens entsprechend dem Alter die sich in einer Verminderung aller Eigenschaften mit Ausnahme der Elastizitet zeigte

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From the Department of Orthopaedic Surgery University of Goteborg Sweden
(Head Professor Carl Hirsch)

THE INTRODUCTION OF FORCE MEASUREMENTS GUIDING INSTRUMENTAL CORRECTION OF SCOLIOSIS

By

CARL HIRSCH & THEODORE WAUGH

Received 21 iii 67

A review of the extensive literature on the etiology of scoliosis reveals a singular lack of facts on which to develop sound hypotheses concerning treatment (*Waugh* 1966) Many authors have advanced theories some of which have been partially substantiated by animal experimentation these have been used to formulate new and presumably improved methods of treatment That these procedures have not stood the test of time has been proved by the still newer methods that have replaced them Such has been the rule but a few exceptions do exist

The Hibbs spine fusion the Risser turn buckle jacket the Milwaukee Brace of Blount and Schmidt are well known but very few others have found a place in the present-day treatment of scoliosis However the realization of the obvious inefficiency of correction techniques which depend upon transmitting pressure through the entire hemithorax to the vertebral column or in applying traction to the skull and mandible has driven many surgeons to adopt a more direct approach to the problem of correction The excision of hemivertebrae for congenital scoliosis has been performed for the past 35 years but it is only recently that opening and closing wedge osteotomies have been performed at the apex of idiopathic scoliosis curves to correct severe deformity In 1955 *Allan* reported a series of scoliosis patients in whom he had inserted a metal jack on the concave side of the curve Since that time several instrumentation techniques have evolved culminating in the 1962 report by *Harrington* of his experience with the use of a compression and distraction device of his own design Harrington has since stated that the correction by this technique was unmatched by any other system There are however many surgeons who would question

the desirability of striving for a straight spine on the grounds that such attempts might endanger the vital contents of the trunk. The occurrence of the occasional castastrophy makes a cautious approach mandatory. However, within these limits it is believed that progress can be made and new attempts should be encouraged to extend our knowledge and improve existing forms of treatment.

At the present time little is known about the etiology of idiopathic scoliosis, the most common variety of lateral deviation of the spine. Encouraging work is being done by *Ponseti* on possible mucopolysaccharide abnormalities in the disease and by *James* on the inheritance. But until such time as the pathogenesis is established and can be controlled, treatment must continue to depend on mechanical correction and maintenance.

Mild and moderate degrees of flexible spinal curvature can be treated successfully by plaster jacket correction and spinal arthrodesis. However, in severe degrees of deformity with minimal flexibility such techniques may produce only 20 per cent to 30 per cent correction with the great likelihood that even this may be lost. It is in the severe cases that spinal instrumentation would appear most useful. The limiting factor however has frequently been the strength of the attachment, particularly to the thoracic area. Many surgeons performing spinal instrumentation have had the unpleasant experience of having their carefully placed hooks cut through the interarticularis. Such are the present problems with instrumentation that some authors in reviewing their patients have not found the results to be an improvement over those obtained with conventional forms of treatment.

With these problems in mind, it was thought to be essential to investigate the strength of conventional methods of attachment to the spine and explore other systems that might be less liable to failure.

A technique which used a mould of the posterior elements of self curing methyl methacrylate was developed which proved to be two to three times stronger than any existing technique of attachment as tested statistically on autopsy specimens. However, toxic properties of this plastic exist due to the free monomer which is present in about 12 per cent concentration with autopolymerization. Although each attachment required only 5 ml of monomer, it was concluded that the implantation of acrylic in a child was not justifiable. It is believed however that the wealth of plastic materials which are being discovered will see the future development of a less toxic substance which would permit the safe use of such a technique.

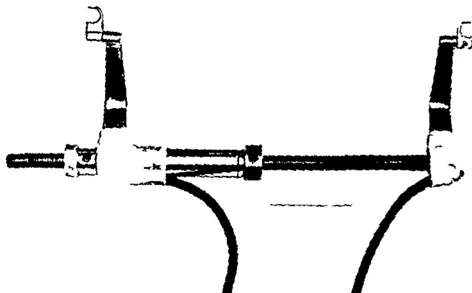


Figure 1 Distraction outrigger with gauges applied

As the limiting factor to the strength of any attachment is the area of contact a stainless steel hook was designed that closely approximated to the anatomy of the thoracic interarticularis and inferior facet Although it had only 9 per cent greater surface area than the largest commercially available hook (Zimmer No 1253) the tested strength was 20 per cent greater It was presumed that a reduction in stress concentration due to the contour caused the difference in levels of failure

When testing of existing forms of attachment on autopsy material it was found that the commercially available *Gruca* hook failed at 55 kp ± 10 This failure occurred before the pedicle to which it would be attached in an anterior alloplasty procedure Because of the increase in angle or spread with the failure of these hooks it was believed that this could endanger the spinal cord Such failure might be corrected by a stronger design if it were desired to exert forces in excess of 45 kp failure would then be limited by the bony attachment and not the device itself

The application to patients of information obtained from testing specimens extravitally, can only be made with considerable reservation No accurate measurement has previously been carried out of the actual force necessary to correct a scoliotic spine nor is any informa

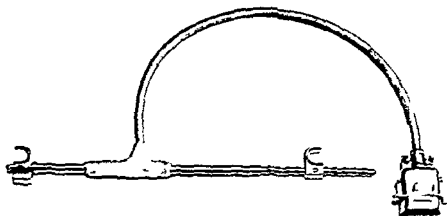
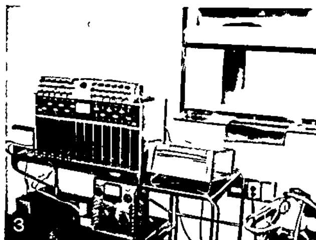


Figure 2 Zimmer No 1250 Distraction Rod with strain gauges isolated by Silastic 382

tion available on the role of various elements in either causing deformity or resisting correction To accomplish such measurements electrical strain gauges were employed on an outrigger device and Zimmer No 1250 rods to act as force transducers (Figures 1–4)

Three patients were selected for intravital measurements who required correction and fusion by the usual surgical criteria The first two patients had moderately severe flexible curves the third a resistant inflexible curve of severe degree Measurements taken during spinal instrumentation procedure indicated that the flexible curves were readily corrected (60 per cent and 75 per cent) by forces of 20–30 kp whereas the inflexible curve was corrected only 25 per cent by forces of this magnitude A force of 38 kp was sufficient to cause failure of the thoracic attachment necessitating reposition of the hook at a higher level (Figures 5–8)

The posterior structures were released to determine which if any of these resisted correction In general there was little change recorded by releasing the paraspinous musculature concave and convex and the interspinous ligaments Section of the apical intertransverse and costotransverse ligaments produced a drop in force in one patient of 4 kp but in another the results were inconclusive



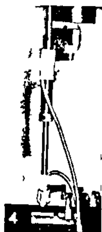


Figure 3 *Electronic equipment for measuring strain (Peekel bridge type 112DA and ABEM Ultralette 5650)*

Figure 4 *Calibration of distraction outrigger in materials testing machine*

Complete paralysis by the injection of 50 ml of celocurin caused a 40 per cent fall in force when compared with that present during deep surgical anesthesia. Coincident with the return of spontaneous respiration, the axial force returned to the original level.

Final correction was accomplished by insertion of the calibrated distraction rod, to which isolated strain gauges were attached, leads being brought out through the skin incision. With complete recovery from anesthesia there was no significant change in the recorded axial force on the rod. Coughing, and particularly vomiting, were associated with brief momentary forces up to 68 kp. Voluntary sitting and standing on the day following surgery produced wide fluctuation in axial force, but the highest figures obtained were only 20 kp.

On reexamining the spinal instrumentation procedure of Harrington on the basis of the information obtained from these extravital and intravital measurements, the weak point of attachment of the distraction rod to the thoracic spine was confirmed. The compression system for the concave side of the curve was found to contribute insignificantly to reduction of the magnitude of the forces on the concave distraction rod. This would raise the question of the desirability of the additional surgery necessary to introduce the compression system.

Investigation of the deterioration curve of the axial force revealed a hyperbolic decline. For this reason, distraction should be attained in slow increments, giving the tissues time to adjust. When utilizing the



Figure 5 Erect roentgenogram of Patient 1

Figure 6 Roentgenogram of distraction rod in situ (Patient 1)

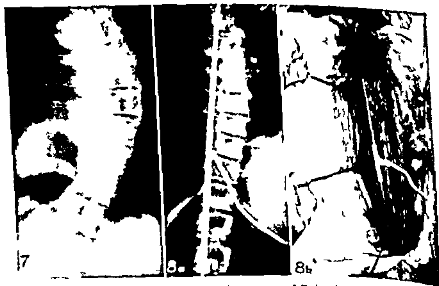


Figure 7 Erect roentgenogram of Patient 9

Figure 8 a b Distraction rod in situ prior to closure (Patient)

present commercially available methods of attachment for the Harrington technique the distraction force should not exceed 30 kp if a good margin of safety is anticipated

While it is not possible to use the measurements obtained to either *advance or negate any of the existing theories of the etiology of idio*pathic scoliosis one cannot but be impressed by several of the findings in this study Contrary to expectation the force necessary to correct moderately severe scoliotic deformity was only in the order of 20–30 kp This might suggest that the forces causing idiopathic scoliosis deformity are of equally small magnitude The paraspinous musculature under anesthesia did not influence the deformity However the intercostal muscles when paralysed significantly changed the recorded axial force This could raise the question of a possible etiological role of the intercostals in the development of idiopathic scoliosis The interspinous ligaments did not appear to influence the deformity and the intertransverse and costotransverse ligaments did so in only one patient On this basis their contribution to the scoliosis deformity is not determinable

SUMMARY

1 *The ultimate strength of lumbar and thoracic laminae has been esti*mated in autopsy material Lateral parts are stronger than medial and lumbar spines tolerate more force than thoracic areas The maximal tolerance was 40 kp in thoracic arches

2 A device has been constructed recording the applied force during correction of scoliosis It was used at surgery in two flexible and one resistant curvature

3 *Forces above 30 kp fractured the laminar bone of the patient* 30 kp was sufficient to correct 75 per cent of the flexible spines whereas the inflexible ones were only corrected 25 per cent by the same force

4 It is suggested that correction should be done gradually perhaps at intervals of several weeks before the final fusion is made

5 The inserted Harrington rods had wire connected built in strain gauges and the leads were brought out through the skin incision Measurements were taken *during the following 24 hours the patient* being allowed to sit and stand The highest figures obtained were less than 20 kp The leads were then removed

RESUME

1 On a procede sur un materiel d autopsie a l appreciation de la force ultime de l arc posterieur des vertebres lombaires et thoraciques Les parties laterales sont plus fortes que les parties medianes et la colonne lombaire supporte une plus grande force que la region thoracique La tolerance maximum est de 40 kp pour les arcs thoraciques

2 Un releve a ete établi enregistrant la force utilisee pour corriger la scoliose Il a ete utilise en chirurgie dans deux courbures flexibles et une resistante

3 Des forces d environ 30 kp entrainent la fracture de l arc postérieur du malade 30 kp suffisent pour corriger 75 pour cent d une colonne flexible alors que les colonnes inflexibles ont ete corrigees avec seulement 25 pour cent de la meme force

4 Il est suggere que la correction soit faite graduellement peut etre avec des intervalles de plusieurs semaines avant d operer la fusion finale

5 Les tiges Harrington inserees sont reliees par fils a des jauges de tension introduites dont les fils sont ramenes a l extérieur par une incision a travers l epiderme Des mensurations ont ete effectuees durant les 24 heures suivantes le malade etant autorisé a s asseoir et a se lever Les plus hauts chiffres obtenus ont été inferieurs a 20 kp Les fils sont alors retires

ZUSAMMENFASSUNG

1 Die ausserste Starke von lumbalen und thorakalen Laminae wurde an einem Autopsiematerial geschäzt Die lateralen Anteile sind stärker als die medialen und Lendenwirbelsaulen ertragen eine grössere Gewalt als Brustwirbel Die grosste Widerstandsfähigkeit war 40 kp im Gebiete der Brustwirbelsaule

2 Eine Vorrichtung wurde konstruiert die die angewendete Kraft während der Korrektur einer Skoliose angiebt Sie wurde während der chirurgischen Behandlung von zwei beweglichen und einer steifen Kurvatur angewendet

3 Kräfte von uber 30 kp brachen den laminaren Knochen des Patienten 30 kp waren ausreichend um 75 Prozent der beweglichen Wirbelsaulen zu korrigieren während die umbeweglichen nur zu 25 Prozent mittels der gleichen Kraft korrigiert wurden

4 Man schlagt vor dass die Korrektur gradweise vorgenommen wer

den sollte moglicherweise in Pausen von mehreren Wochen ehe die endgultige Versteifung ausgefuhrt wird

5 Die angebrachten Harrington Stabe hatten drahtverbundene eingebaute Belastungsmasstäbe und die Leitungen wurden durch den Hautschnitt herausgebracht Messungen wurden während der folgenden 24 Stunden ausgefuhrt und der Patient durfte sitzen und stehen Die hochsten erhaltenen Zahlen waren unter 20 kp Die Leitungen wurden dann entfernt

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From the Department of Orthopaedic Surgery the National Medical Center
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TREATMENT FOR POTT'S PARAPLEGIA

By

BYUNG HOON AHN

Received 5 i 67

INTRODUCTION

Tuberculosis of the spine is today an uncommon disease in Western countries In many other countries however it still has such a high incidence that it represents a constant and important challenge to the orthopaedic profession The antituberculosis drugs have improved the prognosis made possible more effective treatment but have still not solved all the problems

Literature on the treatment of tuberculosis of the spine is voluminous Only a few authors however have dedicated their papers to paraplegia as their main subject The present author feels that paraplegia constitutes such an important problem that it deserves special and separate interest

For that reason it was felt that a review of cases of Pott s paraplegia treated in the Orthopaedic Department of the National Medical Center in Seoul Korea in the years 1959 to 1963 might be of some interest The treatment represented two varying surgical methods—radical evacuation of tuberculous tissue with and without simultaneous anterior spinal fusion This makes it possible to compare the results and evaluate the advantages of these two methods of treatment

REVIEW OF LITERATURE

In this review only publications are surveyed in which the treatment of paraplegia is discussed

Orthodox treatment (constitutional therapy with recumbency immobilisation with or without additional antituberculosis drugs)

The results are not encouraging A reasonable degree of recovery in 54 out of 67 with incomplete paraplegia was reported by *Seddon* (1935)

and complete recovery in 10 out of 23 *Alvil* (1949) Dobson reported on 136 cases in whom one in every four died and less than half made a worth while recovery (*Griffiths, Seddon & Roaf* 1956) Orthodox treatment with the addition of antituberculosis drugs in children was reported by *Kaplan* (1959) as 83 per cent recovery as compared to 58 per cent recovery without drugs

Antero Lateral Decompression

Griffiths, Seddon & Roaf (1956) reported in their above mentioned monograph on Pott s paraplegia the results of antero lateral decompression with 36 recoveries out of 50 paraplegic patients

Radical Evacuation of Tuberculous Tissue

Radical operation before the introduction of antituberculosis drugs was no success Some patients recovered but opening a tuberculous abscess had frequent and serious complications which presented a greater threat to the lift of the patients than the paraplegia Following the introduction of the antituberculosis drugs *Wilkinson* (1949) *Hald* (1950) *Orell* (1951) *Kastert* (1951) *Kondo & Yamada* (1951) started to do a radical operation for tuberculosis of the spine Among their cases were cases with paraplegia *Bosworth* (1953) and *Fellander* (1954) respectively reported four improved out of five patients treated *Paus* (1964) reported the use of this method omitting enforcement of recumbency and immobilisation and had 10 complete recoveries in 21 patients

Radical Evacuation of Tuberculous Tissue with Anterior Spinal Fusion

Hodgson & Stocl (1956) approached the spine anteriorly. After removal of all tuberculous tissue including the surroundings as far back as the spinal cord they inserted strut grafts to keep the vertebral bodies sprung apart Among their first 100 cases they had 35 paraplegic patients with 26 complete recoveries Seventy five of their patients were children

PRESENT STUDY

Material

The material comprises 63 consecutive cases of Pott s paraplegia operated at the Orthopaedic Department of the National Medical Center

Seoul Korea during the years 1959–1963 In this period 315 patients with tuberculosis of the spine were treated at the department The incidence of paraplegia in this series is 20 0 per cent This incidence may be slightly higher than it would have been in a completely unselected group of patients as some paraplegic patients were given priority for admission to the ward

The material was divided into two groups Group 1 includes 33 patients operated by radical evacuation of tuberculous tissue group II includes 32 patients operated by simultaneous anterior spinal fusion Two adults are included in both groups as they first underwent radical operation and later were reoperated by anterior spinal fusion because of unfavourable results

Survey of Patients

Age distribution is given in Table 1 Children and adults in the two groups were nearly identical

Sex distribution There were 31 males and 32 females evenly divided in group I and II

Region of spine involved is given in Table 2 Only six cases involved the cervical or cervico dorsal spine 50 the dorsal and 9 the dorso lumbar spine

Number of vertebra affected averaged 3 2 in group I among the children and 3 4 among the adults while it averaged 3 5 in group II among the children and 2 5 among the adults

Sinus formation was rarely seen in combination with paraplegia

Pulmonary and other tuberculous manifestations Pulmonary tuberculosis occurred in eight of the 33 patients in group I and in 16 of the

Table 1 Age distribution

Age	Number of patients		Total
	Group I	Group II	
0– 4	7	7	14
5–14	9	7	16
15–24	3	2	5
25–44	13	10	23
45–59	1	5	6
60 and above		1	1
	33	32	65

Two adults were included in both groups. (This goes for all tables)

32 patients in group II Other complications occurred in three in group I and three in group II

Observation time is shown in Table 3

Summary The average distribution sex region of the spine involved number of vertebra affected and pulmonary and other tuberculous manifestations did not differ much in the two groups The average observation time is somewhat longer in group I than in group II

Table 2 Region of spine involved

Region	Group I	Group II	Total
Cervical	1	2	3
Cervico dorsal	2	1	3
Dorsal	26	24	50
Dorso lumbar	4	5	9
	33	32	65

Table 3 Observation time

Months	Group I	Group II
3–12	6	5
13–24	7	21
25–36	16	6
37–47	4	–

Survey of Paraplegia

Type (onset) of paraplegia Table 4 shows there were 54 cases of paraplegia where the paraplegia developed within two years after the first spinal symptom appeared and 11 cases were late paraplegia In children 27 were early and three late in adults 27 were early and eight late

Table 4 Type (early or late) of paraplegia

	Group I	Group II	Total
Early paraplegia	27	27	54
Late paraplegia	6	5	11
	33	32	65

Grade of paraplegia is shown in Table 5 In 50 cases the paraplegia was complete in 15 cases it was incomplete 29 in group I had spastic paraplegia four had flaccid paraplegia In group II all had spastic paraplegia including one child who had quadriplegia

Duration of spinal symptoms before operation is given in Table 6

Duration of paraplegia before operation is shown in Table 7

Table 5 Grade of paraplegia

	Group I	Group II	Total
Complete paraplegia	27	23	50
Incomplete paraplegia	6	9	15
	33	32	65

Table 6 Duration of spinal symptoms before operation

Years	Children	Adults	Total
Less than 2	23	22	45
2–10	8	12	20
	31	34	65

Table 7 Duration of paraplegia

Months	Group I	Group II	Total
1– 6	15	12	27
7–12	8	8	16
13–24	8	7	15
25–48	1	4	5
49 and more	1	1	2
	33	32	65

The proportion of complete versus incomplete paraplegia in the early and late type of cases is shown in Table 8 The proportion of complete paraplegia was the same in children and adults *i e* 21 children out of 29 and 29 adults out of 36 The proportion was the same also in early and late paraplegia *i e* 42 in early cases out of 51 and eight late cases out of 11

The proportion of complete versus incomplete paraplegia in relation to the duration of the spinal symptoms is shown in Table 9 Complete paraplegia was more common in cases with a spinal history shorter than two years 24 out of 45 than in cases with a longer history seven out of 20 The figures are too small however to draw any conclusion

Finally *the relationship between the grade of paraplegia and its duration before treatment* is shown in Table 10

Table 8 The proportion of complete versus incomplete paraplegia in early and late paraplegia

	Complete paraplegia		Incomplete paraplegia		Total
	Children	*Adults*	*Children*	*Adults*	
Early paraplegia	18	24	6	6	54
Late paraplegia	3	5	2	1	11
	21	29	8	7	65

Table 9 The proportion of complete versus incomplete paraplegia in relation to the spinal symptoms

Years	Complete paraplegia	Incomplete paraplegia	Total
Less than 2	24	21	45
2–10	7	13	20
	31	34	65

Table 10 Grade of paraplegia in relation to its duration before treatment

Months	Complete paraplegia	*Incomplete paraplegia*	*Total*
Less than 6	25	2	27
6–12	12	3	15
13–24	11	4	15
25 and above	2	6	8
	50	15	65

Treatment

Antituberculosis drug treatment before the patient came to our Out Patient Department In group I only four patients had regular medica

tion for some period of time and in group II one third had relatively regular medication before being seen by us PAS and INH were given to the patients from their first visit to the Out Patient Department of the hospital During their hospital stay streptomycin was given in addition The period of medication (PAS INH) before operation varied between two weeks and 12 months depending on available beds in the ward and thus was left to chance The medication period with SM varied between 10 days and two months After discharge from the hospital medication with PAS and INH were continued for one year or more after operation

Hospitalisation lasted from three to seven days before operation for additional examination and pre operative care Hospitalisation following operation lasted eight days to two months In group I it averaged 29 days and in group II 34 days Of eight patients with more than 60 days five had pulmonary or urinary tuberculosis which needed further hospitalisation and three had complications of short duration

No enforced recumbency or immobilisation was given in group I In group II recumbency in a plaster bed was used for an average of three months in order to facilitate consolidation of the grafts thereafter re placed by a corset the application period of which varied between three and 12 months depending upon the extent of the lesions

Operation Surgery in group I consisted of the evacuation of tuber culous tissue through an antero lateral incision in cervical cases and through a costo transversectomy in the other cases Surgery in group II was done through an antero lateral incision in cervical cases and through a thoracotomy in dorsal cases and thoraco abdominal incision was used in lower dorsal and dorso lumbar cases In group I 27 pa tients were operated on once while six had two operations and in group II 29 patients were operated once and three were operated twice

OPERATIVE FINDINGS

Group I

In group I gross pathology was found in 31 cases inflammatory products were found in 31 cases sequestred material in 30 Small amounts of bone sands were found in three cases Thirty three showed para vertebral soft tissue shadow on radiography an abscess was found in 19 granulation tissue in nine and caseous material in five cases No abscess material was found in three cases

In most cases it was not possible to inspect the cause of paraplegia

because of the limited approach but compression by sequestra was seen in two

By microbiological and histological examination acid fast bacilli and tuberculous granulation tissue were found in 20 cases tuberculous granulation tissue was found in 10 In three cases neither acid fast bacilli nor tuberculous granulation tissue were demonstrated

Group II

In group II the compressing agent was found in all cases The data are given in Table 11

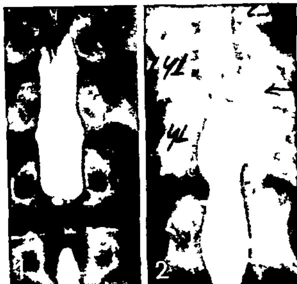
Operative findings in relation to the type (early or late) of paraplegia are given in Table 12

Table 11 The cause of the compression found in 32 cases operated by anterior spinal fusion

Inflammatory product	Abscess		4	9
	Granulation tissue		2	
	Abscess and granulation tissue		1	
	Caseous material		2	
Sequestrated material	Bone	plus inflammatory product	7	14
	Disc		4	
	Bone and disc		3	
	Sequestrated bone and disc	plus fibr adhesion	2	2
Solid material	Bony ridge	plus intr fibrosis	3	7
	Fibrosed mass of disc		1	
	Bony wall (vertebra)			
	Bony ridge and d disc			

Table 12 Cause of compressi e type o a

Inflammatory product
Inflammatory product and sequestrated material
Solid material



Acid fast bacilli only were found in six cases acid fast bacilli and tuberculous granulation tissue in five and tuberculous granulation tissue in 21 cases

COMMENTS ON THE OPERATIVE FINDINGS IN GROUP II

a) *The Compression Agent*

Griffiths Seddon & Roaf (1956) commented on this particular problem and described this form caused by inflexion of the spine bony ridge in the floor of the spinal canal which is the commonest cause of late onset of paraplegia *Hodgson* (1960) reported on a similar case The present author observed seven cases of this particular cause of paraplegia

b) *The Relationship to the X Ray Findings*

Plain X ray and tomogram gave little information as to the cause of paraplegia even in cases where bony spurs were found to be the cause of compression at operation

Myelography on the other hand gave valuable information In one case a sharp indentation in another a complete block was demonstrated (Figure 1) In one case with concentric compression and strangulation of the dura myelography showed an "hour glass formed

shadow (Figure 2) Three cases in the healing stage of paraplegia showed a complete block with small ears of contrast medium pointing to the periphery of the spinal canal Complete block seems to correspond to an extradural space filled up with fibrosis and adhesions

RESULTS OF OPERATION

The results of operation in group I and II are respectively given in Tables 13 and 14

As to the three children who had no recovery in group I all had extensive lesions and in one case the failure was proved to be due to collapse of the cord following operation which was observed at the second intervention In another the failure may be due to a similar cause The third died of pneumonia after three months

Table 13 Results of operation in Group I

Results	Children	Adults	Total
Complete recovery	13	10	23
Incomplete recovery	–	4	4
Failure	3	3	6
	16	17	33

One adult who recovered completely from completely paraplegia afterradical operation however later developed recurrence of paraplegia is included

Table 14 Results of operation in Group II

Results	Children	Adults	Total
Complete recovery	14	14	28
Incomplete recovery	–	4	4
	14	18	32

COMPLICATIONS

In group I serious complications consisted of damage to the cord in two cases during surgery with subsequent complete paraplegia and the two earlier mentioned cases of excessive collapse during operation In one case a sinus formation in the wound healed after one month

In group II there were no serious complications One thoracic duct was damaged when the intercostal arteries were divided close to the aorta Immediate ligation was successful In one case the lower end of the graft was found to be displaced two months after operation Re operation gave subsequent healing Fracture of the graft was found in the post operative period in 11 cases where more than four vertebrae were affected and totally removed They all healed subsequently

There were no fatalities in either group in the immediate post-opera tive periods In group I one child and one adult died from pneumonia *three to 12 months after operation and a third died after six months* cause unknown

In group II there were no fatalities in the follow up period

Factors Influencing the Results of Treatment

Age In this series the age of the patients seems to affect the results of treatment in the quality of the recovery and in the rapidity in re gaining walking capacity after operation

In group I complete recovery occurred in children in 13 out of 16 81 2 per cent in adults in 10 out of 17 58 7 per cent Walking capacity within six months was established in 11 out of 16 in children 62 5 and in adults 6 out of 17 35 5 per cent In group II complete recovery occurred in children in 14 out of 14 100 per cent and in adults in 14 out of 18 78 3 per cent Walking capacity within six months was established in children in nine out of 14 64 2 per cent and in adults in nine out of 18 50 0 per cent

The Duration of the Spinal Symptoms (until Operation)

In group I complete recovery occurred in 16 out of 21 76 2 per cent in patients with duration of the spinal symptoms of less than two years and in seven out of 12 58 3 per cent in patients with longer symptoms Walking capacity showed no difference In group II dura tion of the spinal symptom had no influence either upon the quality of recovery or upon the rapidity in regaining walking capacity

The grade of paraplegia In group I complete recovery occurred in 18 out of 27 66 6 per cent in patients with complete paraplegia and in five out of six 83 3 per cent in incomplete paraplegia In group II complete recovery occurred in 19 out of 23 82 6 per cent in patients with complete and in nine out of nine 100 per cent in incomplete para plegia

ing part of the vertebra and disc were removed in connection with anterior spinal fusion In this group an antero lateral cervical approach and a transthoracic or a thoracoabdominal approach were used

The operative findings and the treatment results are compared and discussed The transthoracic approach gave an excellent opportunity to inspect and to remove the compressing agent and seems to be preferable *in cases of longstanding* paraplegia where the compressing agent is often formed by solid masses

This approach furthermore makes it possible at the same time to stabilise the spine by anterior fusion

RÉSUMÉ

Deux groupes pratiquement similaires de paraplegie de Pott en tout 65 cas sont rapportes Dans le groupe I il a été pratiqué une extirpation radicale du tissu tuberculeux par incision cervicale antero laterale ou par costo transversectomie Dans le groupe II le tissu tuberculeux et l entourage de la vertebre et du disque intervertebral ont eté retires en liaison avec une fusion spinale anterieure Dans ce groupe on a eu recours a une approche antero latérale cervicale une transthoracique ou une thoracoabdominale

Les trouvailles operatoires et les resultats du traitement sont comparés et discutés L approche transthoracique a donné une excellente possibilite d examiner et d eliminer l agent de la compression et semble etre preferable dans les cas de paraplegie de longue duree ou l agent de compression est souvent forme de masses solidifiees

Cette approche permet en outre de stabiliser simultanément la colonne vertébrale par fusion anterieure

ZUSAMMENFASSUNG

Über zwei fast gleichartige Gruppen von Pott scher Paraplegie insgesamt 65 Falle wird berichtet In der ersten Gruppe wurde eine radikale Entfernung von tuberkulosem Gewebe mittels einer antero lateralen cervikalen Inzision oder mittels Costo transversektomie ausgefuhrt In der zweiten Gruppe wurden das tuberkulose Gewebe und der umgebende Teil des Wirbels und des Diskus im Zusammenhang mit einer vorderen Wirbelversteifung entfernt In dieser Gruppe wurde ein antero lateraler cervikaler Zugang ein transthorakaler oder ein thorakoabdominaler Zugang verwendet

Die operativen Befunde und Behandlungsergebn[illegible] glichen und besprochen Der transthorakale Zugang [illegible] zeichnete Moglichkeit das komprimierende Agens zu [illegible] zu entfernen und scheint bei Fallen von langdauernde[illegible] denen das komprimierende Agens oft von soliden Ma[illegible] vorzuziehen zu sein

Dieser Zugang macht es ausserdem moglich die V[illegible] zeitig mittels vorderer Fusion zu stabilisieren

ACKNOWLEDGEMENT

The author wishes to express his deep gratitude to two of the [illegible] orthopaedic department the National Medical Center Seoul [illegible] Paus M D present chief of the Martine Hansens Hospital [illegible] Professor Arnt Jakobsen M D present chief of the Laegevakt [illegible] gave me constant instruction and revised my work with untiring [illegible]

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SURGICAL PROBLEMS IN HEMIPELVECTOMY

By

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Received 16 xi 67

By hemipelvectomy is meant an amputation in which the plane of re section runs in principle from the symphysis to the sacro-iliac joint half the pelvis and the extremity being amputated Synonyms are hind quarter amputation and interpelvi abdominal amputation

The first hemipelvectomy was performed in 1889 by *Billroth* but with a fatal outcome The first successful operation by Girard came in 1895 (*Pringle* 1916) A total of 138 hemipelvectomies had been re ported by 1946 (*Wise* 1949) though with a high operative mortality Several large series have been published since for instance by *Gordon Taylor & Monro* (1952) and *Pack & Miller* (1964) and the operative mortality in these is considerably lower only 2 per cent in the latter This progress is chiefly ascribable to improved anaesthesia and shock therapy The indications for hemipelvectomy have been extended as knowledge of the biology and classification of the mesenchymal tu mours has increased Prosthetic improvements moreover have helped to reduce the functional invalidity resulting from the operation

Experience has thus shown that this major surgery can be under taken without undue risk The purpose of the present paper is to dis cuss the surgical principles including the pre and postoperative assess ments involved in hemipelvectomy Our series of 13 cases is briefly reported at the same time

INDICATIONS

The main indication for hemipelvectomy is the presence of a malignant mesenchymal tumour in the vicinity of the hip-joint with dissemina tion within the pelvic or the gluteal region Among the bone tumours chondrosarcoma in the pelvis is the most common indication (Figures



Figure 1 *Chondrosarcoma in the region of the ischial tuberosity*

Figure 2 *Chondrosarcoma emanating from the deep surface of the acetabulum and displaying pronounced intrapelvic expansion*

1 and 2) fibrosarcoma being the most common among soft tissue tumours If the tumour lies distal to the inguinal ligament but proximal in the thigh hemipelvectomy may be necessary in order to ensure a sufficiently radical resection Moreover since there is little functional difference between an exarticulation and a hemipelvectomy prosthesis the more radical measure can be recommended if it makes complete removal of the tumour more certain Hemipelvectomy can also serve as a palliative measure if intrapelvic expansion caused by the tumour elicits compression symptoms from urinary tract intestine or lumbar plexus *Pack & Miller* also list skin tumours (melanoma) as an indication for hemipelvectomy The use of this operation for pelvic osteomyelitis has been reported earlier but not in recent years no doubt owing to improvements in antibiotic therapy We have no personal experience of the last two indications

PREOPERATIVE ASSESSMENT AND EXAMINATION

A correct diagnosis is obviously of fundamental importance for the surgical procedure As for bone tumours in general this calls for close cooperation between pathologist roentgenologist och orthopedic surgeon We prefer surgical exploration a biopsy always being performed so that the tissue samples for histopathological diagnosis are as representative as possible The examination may be supplemented by needle biopsy for a cytological diagnosis

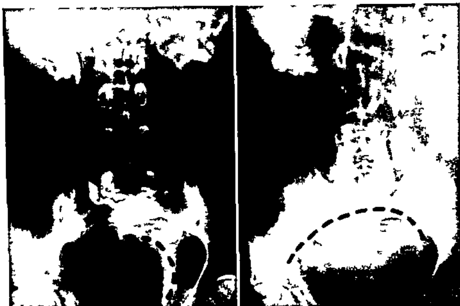


Figure 3 Urography in the same case as in Figure 2 The examinations were performed with an interval of 2 months the patient having refused treatment after the first one The righthand picture clearly shows dislocation of the contralateral ureter

If the tumour has spread within the pelvis urography and colon x rays should always be undertaken in order to visualize the topography (Figure 3) One can then plan an extention of the operation in advance If proliferation of the tumour makes it necessary to resect the ureter a nephrectomy on the affected side must be done in conjunction with the hemipelvectomy The urography will also provide preoperative information about renal function If the colon is invaded by the tumour a preoperative colostomy may be indicated

An angiographic survey is often needed particularly to locate the pelvic arteries Here it may be noted that the femoral artery on the healthy side should be used for injection of the contrast medium In several of the cases in which the angiography was performed via the diseased leg s femoral artery subsequent vascular dissection was complicated by hematoma oedema or perivascular fibrosis This difficulty was specially marked in a case in which the external iliac artery had previously been catheterised for perfusion treatment with cytostatics Angiography via the femoral artery on the healthy side also provides information about the circulation on both sides distal of the aortic

bifurcation If it is then found for instance that the contralateral internal iliac artery displays pronounced arteriosclerotic changes allowance can be made for this at hemipelvectomy by avoiding ligature of the common iliac artery Ligation of only the external branch leaves the ipsilateral internal iliac artery unimpaired thereby guarding against circulatory disturbances in the pelvic organs It is possible however that this danger has been exaggerated In a case of uterine rupture bilateral ligation of the internal iliac arteries did not give rise to any complications in the form of circulatory disturbances (*Sjovall* 1966)

The preparations for hemipelvectomy may also include the introduction of a ureteric catheter If the tumour has expanded into the pelvic cavity it may be easier to locate the ureter by palpation of the catheter via the ureter wall A bladder catheter is always introduced if the hemipelvectomy is expected to take a long time

SURGICAL TECHNIQUE AND COMMENTS

The operation is performed with the patient supine a small wedge shaped pad sometimes being placed under the lumbar region on the affected side We consider this position advantageous because it permits rapid retroperitoneal dissection to the major pelvic vessels which can then be controlled The lateral position reported by *Sorondo & Ferre* (1946) does not afford the same advantages

The incisions are placed according to the tumour s extent particularly in the dorso proximal direction A large anterior incision is generally made first running along the greater part of the iliac crest to the ventral iliac spine and from there along the inguinal ligament to the pubic tubercle and the symphysis The abdominal musculature is freed from the iliac crest and the pubic tubercle the peritoneum and the ureter are retracted medially and the vessels are followed in a proximal direction The common iliac artery and vein are dissected free independently and fitted with rubber occlusion clamps as a precautionary measure As pointed out by *Wise* (1948) and others one then has complete control in principle of major intrapelvic bleeding in the operation field

Once it has been established that the tumour is operable the major vessels are ligated and cut In most cases we have severed the external iliac artery and vein in 3 cases the common vessels and in 1 case—owing to the anatomical relationships—the external and internal ves

sels independently A sufficiently radical excision of the tumour can generally be achieved with severance of only the external vessels This also avoids the danger of circulatory disturbances arising in the region supplied by the internal iliac artery This point has been heavily emphasised by *Ravitch* (1949) who holds that only the external artery can be severed with impunity *Gordon Taylor & Monro* (1951) *Pack & Miller* (1964) and *Phelan & Nadler* (1964) always sever the common vessels apparently without adverse effects In the cases in which we ligated the common (or internal) iliac artery no necrosis developed in the gluteal region It would seem that the collateral circulation is sufficient to maintain viability The femoral nerve and the psoas muscle are cut at the same level as the vessels

The posterior and medial parts of the skin incision form the next step The leg is adducted and rotated strongly inwards the posterior incision being placed in a wide arc from the posterior superior iliac spine to the greater trochanter from where it turns down the gluteal fold towards the ischial tuberosity From there it runs on the medial aspect along the pubic arch to the cranial border of the symphysis

In the gluteal region we aim at retaining the gluteus maximus muscle so that after the amputation it can be sutured to the abdominal musculature and form a cover over the amputation field giving a stump of suitable consistence and strength For this reason we sever the muscle at its attachment in the gluteal tuberosity and the fascia lata In only 1 of our cases was the muscle resected the defect being replaced with a tantalum net Neither in this nor the other cases has hernia developed in the amputation stump

The myotomies are followed by subperiostal exposure of the region for the osteotomies at the symphysis and ilium We generally make the anterior osteotomy through the pubic bone about 1 cm lateral of the symphysis in order not to risk injury to structures in the urogenital trigonum A Gigli saw is used for the osteotomy The pubic angle is extremely acute in some men making it difficult to pass the saw round the bone In such cases the anterior cleavage of the pelvic girdle had to be done through the symphysic cartilage

With respect to the posterior osteotomy prosthetic function and cosmetic considerations call for a resection plane that saves as much of the ilium as possible The location of the tumour may however necessitate a very dorsal osteotomy in the sacro-iliac joint or even through the lateral part of the sacrum If the osteotomy is made through the ilium the plane of resection coincides with the greater sciatic notch

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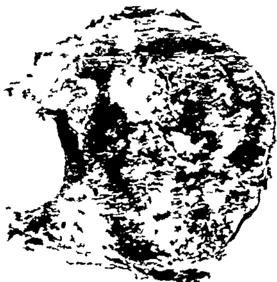


Figure 4 Frontal section of the condrosarcoma in Figure 2 The small incisure to the left is the acetabulum from the base of which the tumour measuring 11 × 11 cm is proliferating



Figure 5 Hemipelvectomy specimen (frontal section) of a synovial sarcoma The tumour has grown through the obturator foramen into the pelvic cavity

2 Performing the osteotomies in swift succession facilitates dissection of the tumour and control of bleeding

3 Encapsulated tumour with an extensive intrapelvic expansion accompany the pelvis after the osteotomies

4 The gluteus maximus muscle should be spared and used to build up an optimal stump Resection of this muscle does not however necessarily result in insufficiency of the pelvic floor

5 Owing to the volume relationships a hemipelvectomy is considerably easier to perform on a child than on musculous or corpulent adults

POSTOPERATIVE TREATMENT

In our experience the patient is surprisingly unaffected by this major operation Mobilisation is therefore possible on the 1st or 2nd postoperative day when the patient is stood up on the remaining limb Walking exercises with a walking chair or supports are started as early as in the first postoperative week As a rule the first prosthesis can be moulded about 3 weeks after the operation

THE AUTHORS SERIES

Our series comprises 13 hemipelvectomies The age sex and diagnosis for these patients are reported in Table 1

Table 1 13 hemipelvectomies

Female	4	46–68 years
Male	9	11–69 years
Fibrosarcoma		3
Synovial sarcoma		2
Angiosarcoma		1
Chondrosarcoma		5
Osteosarcoma		2

There have been no immediate postoperative deaths All the patients were discharged from the hospital with a prosthesis and varying degrees of walking function The shortness of the present observation time—6 months to 4 years—precludes any assessment of the long term prognosis It may be mentioned that *Pack & Miller give the 5 year* survival rate after hemipelvectomy for soft tissue tumours as 26 9 per cent and for bone tumours as 20 per cent Our results to date are not

unfavourable (see Table 2) but more experience is required for an adequate assessment

Table 2 13 hemipelvectomies
Observation time 6 months–4 years

	I	II
Alive without metastases	4	2
Alive with metastases	1	1
Dead	1	4

I = soft tissue tumour
II = bone tumour

SUMMARY

The surgical considerations and technique in hemipelvectomy are discussed in detail with particular reference to methods for reducing operative complications In the authors series presented here—13 cases with a maximal observation time of 4 years—there have been no deaths during or immediately after the operation

RÉSUMÉ

Il est discuté en détail des considérations chirurgicales et techniques de l'hémipelvectomie en particulier par rapport aux méthodes pour réduire les complications opératoires Dans les séries des auteurs présentées ici – 13 cas avec une période maximum d'observation de 4 ans – il n'y a pas eu de décès pendant ou immédiatement après l'opération

ZUSAMMENFASSUNG

Die chirurgischen Überlegungen und die Technik bei der Hemipelvektomie werden eingehend und mit besonderer Bezugnahme zu Methoden die operative Komplikationen herabsetzen besprochen In der von den Verfassern hier vorgestellten Gruppe – 13 Fälle mit einer maximalen Beobachtungszeit von 4 Jahren – ereignete sich kein Todesfall während oder unmittelbar nach der Operation

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From Sophies Minde Ortopedisk Hospital Oslo (Head Ivar Alvik) and
The Department of Orthopaedic Surgery The University of Washington

CAPITAL FEMORAL EPIPHYSIOLYSIS TREATED BY PLUGGING WITH CORTICAL BEEF BONE

By

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Received 8 ii 67

Treatment of capital Femoral epiphysiolysis by plugging or epiphysiodesis is well established though not widespread and has been used in several hundred cases In the reported cases autogenous cancellous bone of local and iliac origin has been used At Sophies Minde cortical beef bone processed in the hospital is used The purpose of this report is to evaluate this technique and also to emphasize again a valuable early radiological sign in epiphysiolysis which has previously been described

Two results are sought from the plugging operation the prevention of further slip and accelerated closure of the cartilaginous growth plate An advantage is that no second operation is required to remove metallic fixation material such as a Smith Petersen nail or threaded pins Possible disadvantages are that in the plugging operation which is intracapsular infection if it occurs will be very serious and that the incidence of ischemic necrosis of the femoral head might be increased

DIAGNOSIS

The usual diagnostic signs and symptoms sought upon hip or knee complaints in an adolescent are well known. A less well known early radiological sign has been described by *Capener* (1956) *Durbin* (1960) and *Jacobs* (1962) This is the extrusion of the diaphyseal component of the caput femorale from the acetabular contour and is seen on the frontal film This means that the dense triangle normally seen below the caput s main epiphyseal portion and resulting from overlapping of the lower part of the acetabulum with the diaphysis of the neck, is not present. Of course the usual other radiological findings are found, particularly those on the lateral view But this sign is occasionally the only finding in an early case as in

4 of 24 hips *Jacobs* reviewed It was the only sign in 1 and possibly 2 *of the hips* in this paper As *Jacobs* points out it is of special value when the clinical diagnosis *is unsuspected so that a lateral film* is not taken For example in the usual follow up of a patient with known unilateral disease without complaints on the opposite side lateral films on that side may not perhaps be made In these cases it is a particular advantage to be able *to utilise a sign visible early* on a routine film and offering a very high degree of reliability

In case 5959 of this report it is seen in the clinically normal right hip which went on to undiagnosed slip and progression See *Figure 7 a–e The final appearance* in the hips of this case is that frequently seen in hips which some surgeons feel are particularly susceptible to osteoarthritis This suggests that undiagnosed epiphysiolysis may be a more common cause of Primary osteoarthritis than is generally realized

MATERIAL

Thirty six patients whose clinical records and x ray folders were studied are reported For the purposes of this report *final clinical examination of the patients* by the author was not necessary Nineteen were boys and seventeen were girls giving the anticipated slight male preponderance Four boys and four girls had bilateral disease an incidence of bilaterality of 22 per cent Because thirteen uninvolved epiphyseal plates were open at the last follow up a slightly higher bi*laterality rate could occur Thirty two cases had slipped* less than 30 per cent 7 between 30 and 50 per cent and 4 over 50 per cent One case could not be evaluated for degree of slip Two of the minor slips were discovered only *on reviewing* the *x rays and being clinically unrecognized were untreated*

The average age at operation was 13 years 1½ month The oldest was a boy 15 years and 7 months old and the youngest a girl 9 years and 10 months old without a history of trauma The average boy at *operation* was 13 years 11 months old the average girl 12 years and 2 months The coincides with the usual age *difference of 2 years between* boys and girls presumably related to difference in bone age

TREATMENT (See Table 1)

The two S P nailings were performed elsewhere before admission to Sophies Minde Of the 10 osteotomies 8 were intertrochanteric one was sub capital and one was through the lower third of the neck They were all fixed with staples except for the sub capital one which was held with the bone plugs Five of the intertrochanteric *osteotomies had bone plugs introduced through the osteotomy site*

Table 1 Treatment of 44 hips

Total number with plugging alone	29
Total number with osteotomy alone	2
Total number osteotomy plus plugging	8
Total number with S–P nail	2
Total number *untreated*	3
Total number of hips involved	44

On admission the cases were placed in slightly abducted otherwise straight bilateral skin traction of 2-3 kilograms A few had tibial skeletal traction Surgery was not done as an emergency The incision approach was between the tensor fascia lata and gluteus medius The capsule is longitudinally incised and the neck and site of slip seen Drill holes of about 1/4 inch are made into the head through the neck starting antero laterally Cortical beef bone plugs are then shaped to fit and driven in according to length determined by placing a thin K wire into the drill hole and rotating the femur to see when the wire no longer moves with the femoral neck. The capsule is loosely closed Traction continues for 10 weeks after surgery Active and passive exercise begins one to two weeks after surgery Traction is discontinued at 10 weeks but bed rest continues 6 weeks longer Then gradual weight bearing with crutches begins

Roentgen films are made at 10 and 16 weeks and thereafter at intervals of several months

RESULTS

1 *Obliteration of the Growth Plate*

Seventeen male hips were evaluated in this respect and twelve female hips both groups being treated with plugging Fourteen normal hips five male and nine female were also evaluated The results are in Table 2 These times seem rather long It should be stated that what is referred to here is complete disappearance of the cartilaginous growth plate including the small portion laterally which was generally seen to disappear last Bone trabeculae crossed the plate in every case earlier usually by several months However it is difficult to evaluate when bone trabeculae first cross a plate or when there are enough crossing to assure stability Therefore the endpoint of 100 per cent closure was chosen If the plate were almost closed at one date and completely closed on the next study several months later the latter time was chosen See Figures 1 2a b 3 and 4a b c to see when closure is accepted in comparison to when closure for clinical purposes is apparent

Table 2 Obliteration of growth plate time after plugging and age in normal and plugged hips

	Male	Female
Average age following plugging operation	15 years ? months	13 years 4 months
Average time following plugging operation	12 9 months	14 month
Average age in normal hips	16 years 7 months	13 years 11 months



Figure 1 Closure is not roentgenologically complete but clinically adequate



Figure 2 a) both not considered completely closed b) was taken 9 months after operation



Figure 3 Almost 2 years after surgery clearly clinically closed but not 100 per cent roentgenologically

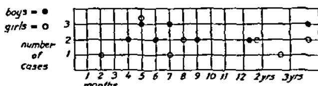


Figure 4 a b c a) Is clinically closed as is 4 b Full roentgenological closure was accepted with 4 c 15 months after surgery

Howorth reporting on results with autogenous iliac plugs in 1965 reported obliteration of the epiphyseal plate within a year *Heyman* *Herndon* in 1954 reported that cancellous bone plugs produced roentgenographic evidence of fusion within three months after operation In the present series though average obliteration took a little over a year these were average values Several cases took well over one year suggesting that beef cortical plugs are not as efficient in this regard as are autogenous cancellous plugs See Table 3

No cases in this series slipped after plugging so that clinically adequate healing actually occurred within four months when ambulation began

Table 3 Breakdown of closure times
Three boys and 3 girls required over 2 years for full plate obliteration



2 *Evaluation of Matters of Technique Bone Plugs*

79 plugs were used As evaluated on routine 2 view study and regarding the concavity of the growth plate 13 or 16 per cent of plugs did not cross the plate In three of the 37 cases plugged or 8 per cent no plugs crossed None of these cases slipped further

In 6 cases a plug protruded through the head into the joint space and in one the plug clearly entered the acetabular cartilage No harm was noted except in the latter case to be discussed later Bone in the joint space either backed into the head or broke off the loose fragment usually becoming invisible within one year

In many cases plugs at the site of entry into the neck were allowed to protrude to a varying degree above the neck surface This protrusion either resorbed or rounded out and only one case to be discussed became a problem

In distinction to autogenous cancellous bone beef cortical plugs are visible clearly on x ray study for a long period Initial host invasion as determined by distinct rather uniform serrations on their edges was seen an average of 4 months after operation The time required for complete plug disappearance varied greatly a few becoming invisible in 1 year and some clearly visible after six to eight years

Figure 5 a b Shows plug fragments unchanged in 7 years



Figures 5a and b show bone plugs protruding on the neck unchanged 7 years after surgery

Osteotomies

Of the 7 intertrochanteric osteotomies and one just above the greater trochanter all fixed with staples which were treated similarly to plugged cases afterwards all healed in 3 to 4 months Five of these had plugs through the osteotomy site which in no apparent way interfered with healing

A sub capital osteotomy held with the bone plugs through the neck fell apart It was then reduced and fixed with an S P nail Interestingly this case a 50 per cent slip at the start did not develop necrosis with a follow up of 3 years and 4 months The 10th osteotomy was through the lower third of the neck held with 2 staples It dislocated and required re operation with new fixation applied on the neck Necrosis and deformity followed

Antibiotics and Infection

No infections occurred

Over one half of the cases received Penicillin from the day of surgery to a variable post operative period See Table 4 There is no significant difference in the post operative temperature curve for the two groups

Table 4 Comparison of average temperature curves 10 days post op in cases with plugging only with and without antibiotics

Post op day	1	2	3	4	5	6	7	8	9	10
Penicillin	38.4	38.0	37.8	37.8	37.8	37.[illegible]	37.6	37.6	37.4	37.4
No antibiotics	38.5	38.1	38.1	37	37.6	37.6	37.5	37.4	37.5	37.4

Complications

See Table [illegible] [illegible] necrosis [illegible] eleven hips [illegible] 30 per cent [illegible] an incidence of [illegible] per cent.

This includes [illegible] was one hip [illegible] 20 per cent [illegible] necrosis. I was [illegible]

[illegible]

[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]

[illegible]

A Necrosis

1 *Case 11221* [illegible] 80 per cent [illegible] reduced with preoperative traction [illegible] reduction was attempted [illegible] joint space broke off [illegible] 2 [illegible] be seen after 10 months. Necrosis [illegible] surgery seems due to an extensi[illegible]

2 *Case 8332* Over [illegible]0 per cent slip [illegible] placed plugs and osteotomy through [illegible] th with staples. Osteotomy was displaced [illegible] new staples. Necrosis and deformity in 1 [illegible] ther and 2 operations on the neck may well [illegible] eriod

3 *Case [illegible]* 10 per cent slip with ca[illegible] n plate into the joint broke and backed into the h[illegible] uccessful ties. The patient was a diabetic. Necrosis [illegible] Cause not clear. This was the only hip [illegible] associated develop necrosis [illegible] ases that

4 *Case 8[illegible]66* 30 per cent slip with ca[illegible] of acute sule not opened. Treated with intertroc[illegible] ple plugg through osteotomy site. Necrosis and [illegible] ted to in- not clear

5 *Case 8389* 30 per cent slip with ca[illegible]



Figure 6 a b c Damage to left head from bone pegs advanced 4 months after operation

sule not opened Treated same as case 8566 Necrosis and deformity in 17 months Cause not clear

6 *Case 10325 L* 50 per cent slip without callus treated elsewhere with *manipulation and S P nail Necrosis and deformity in 1 year* Possibly attributed to extensive acute slip and manipulation

Only one case of necrosis no 3 occurred in a case treated by the plugging operation alone in a slip of a mild degree In the 6 cases with necrosis the average time for obliteration of the growth plate was 8 8 months less than the average for the series

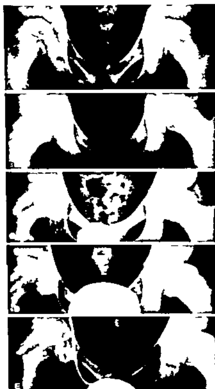
B *Direct Mechanical Damage from Plug*

In case 8850 L a 15 per cent slip with callus two bone pegs entered the acetabular cartilage Free movement in the joint immediately after operation was recorded Damage to the dome of the head was suggested 2 months later and advanced in 4 months See Figure 6 This was a complication from a technical error With the plug fixed at both ends motion damaged the surface of the head

C *Bone Graft Effect Causing Mechanical Obstruction to Joint Motion*

Case 5959 which also developed necrosis developed a large mass of bone over the protruding ends of the plugs on the femoral neck This grew to a size where it impinged on the edge of the acetabulum Se Figure 7 a–c

Figure 7 a–e Progression of slipping in unsuspected right hip and bone graft effect in plugged left hip The photos are reversed



DISCUSSION

Bone plugging with cortical beef bone in epiphysiolysis is a clinically successful method The time required for obliteration of the cartilaginous growth plate is diminished though probably not so well as with autogenous cancellous bone Further slipping has not occurred either in pre operative traction or at any time in the post operative period One may speculate that drilling across the cartilaginous growth plate alone associated with over 6 weeks of traction might be a successful form of treatment but it seems unworthy of clinical trial

One patient in this series who underwent simple plugging associated with opening of the capsule developed necrosis Five other cases that developed necrosis could either be explained by the degree of acute slip could not be explained though *not* treated with the simple plugging operation or in one case the necrosis was probably related to inadequate fixation of a cervical osteotomy

Two complications were related to positioning of bone plugs and could have been avoided with more careful surgical technique

SUMMARY

A series of 44 hips with capital femoral epiphysiolysis is reviewed most of which were treated by plugging with cortical beef bone plugs

Complications due to the method are described and found for the most part to be avoidable

The method is found to be successful though probably not as fast in causing obliteration of the cartilaginous growth plate as that using autogenous cancellous bone

A valuable roentgenologic diagnostic sign previously described in the literature is emphasized

RESUME

Une série de 44 hanches avec epiphysiolyse de la tete femorale est reexaminée la plupart ayant été traitees par enchevillement avec chevilles d os cortical de boeuf

Les complications decoulant de la methode sont decrites en demontrant que la plupart peuvent cependant etre evitees

On considere que la methode a ete un succes probablement pas tellement parce qu elle produit une oblitération de la croissance de la croissance de la plaque cartilagineuse que parce qu elle utilise de l os spongieux autogène

Il est souligne comme cela a ete prealablement décrit dans la litté rature qu il est precieux d avoir un bon diagnostic radiologique

ZUSAMMENFASSUNG

Eine Grupe von 44 Huften mit Epiphyseolyse des Femurkopfes wird besprochen Die Merzahl der Huften wurde mittels Einschlagen von kortikalen Ochsenknochenpflocken behandelt

Komplikationen die im Zusammenhang mit der Methode stehen werden beschrieben und man findet dass sie grostenteils vermeidbar sind

Die Methode ist erfolgreich obwohl sie wahrscheinlich *nicht* so rasch zur Obliteration der Epiphysenplatte führt als die welche autogenen Spongiosaknochen verwendet

Ein wertvolles rontgenologische diagnostisches Zeichen das fruher in der Literatur beschrieben wurde wird hervorgehoben

ACKNOWLEDGEMENT

I would like to thank Professor dr med *Ivar Alvik* for allowing me access to all necessary material at Sophies Minde To dr *Victor Segalstad* I am grateful for help in evaluating roentgenograms wherever needed and particularly for calling my attention to the roentgenological sign described here

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From the Department of Orthopaedic Surgery University of Goteborg Sweden
(Head Professor Carl Hirsch)

OSTEOTOMY IN OSTEOARTHRITIS OF THE HIP JOINT

A Follow up Study

By

CARL HIRSCH & IAN GOLDIE

Received 13 II 67

THEORETICAL CONSIDERATIONS

The clinical picture of osteoarthritis of the hip is well recognized and characterized by pain and restriction of motion At an early stage the symptoms are temporary later chronic disturbances may cause severe disabilities The discrepancy between the clinical and radiographic appearance is sometimes striking and the prognosis is hardly predictable (*Danielsson*) Surgical interventions will have to rely entirely on the evaluation of the patient s situation the need changing for each individual person

The pathomorphologic features are well recognized the damage to the cartilage (*Chung*) gives rise to a number of phenomena osteophytes and subchondral bone disturbances (*Pommer Lang, Sawyer* and *Ghormley Trueta*) intraosseous circulatory disorder (*Trueta Hulth*) presence of granulation tissue (*Harrison Schajowicz Trueta*) and nerve elements close to erosion areas in the cartilage (*Miller* and *Kasahara*) and inflammatory reaction in the synovial tissues Some physiochemical properties of blood from osteoarthritic joints have also been claimed to differ from normal (*Katayama et al*)

There has long been evidence that cartilage can suffer from mechanical forces interfering with the physical properties of the joint surfaces Inadequate pressure per unit cartilage area causes residual deformations of longer duration This appears to be the case in joints where incongruency exists (*Wiberg Hirsch Steindler*) But even between congruent surfaces some areas are more subjected to pressure than

others In the hip joint the pressure area is located towards the anterior superior part of the femoral head (*Truela Frankel Rydell*) This is the place where early pathoanatomical changes start (*Truela*)

All this information has yet not yielded a complete understanding of the mechanism of pain However attempts have recently been made to utilize the presence of subchondral tissue reactions with its nerve supply into a theory of pressure sensitive areas (*Hirsch*) Force measurements obtained from a replacement femoral head prosthesis indicated the magnitude and direction (*Rydell*) The findings suggested that the compression area of the femoral head hardly escaped mechanical strain Walking at an increasing speed increased the force while the use of a cane and slow movements gave a marked relief Once the compression area due to its pathology has become increasingly sensitive clinical symptoms appear It then seems logical to look for measures by which the pressure should be decreased or distributed in other ways allowing sensitive areas to escape to a certain extent the mechanical strain

Clinical experience from various surgical interventions may well fit into such a mechanical way of explaining favourable results Since the stress distribution is a function of body weight and the anatomical shape of the upper femur and muscle action procedures such as myotomies tenotomies or neurotomies will alter the mechanical conditions A similar result might arise if the anatomical relationships are altered by an intertrochanteric osteotomy Both these procedures muscle release and osteotomy might introduce other areas as pressure zones where none or less sensitive bone destruction is present If the pressure zone on the femoral head as indicated above is rather limited the degree of clinical result in terms of less pain would then depend upon the type of pathology that is introduced to take over the mechanical strain Early interventions that is to say in less advanced cases with good mobility would adjust the joint preoperative limitation of movement may not

Other theories trying to explain the effect of osteotomy take into consideration not only changing but mainly increasing the area of weight bearing whereby the pressure per unit area decreases (*Pauwels*) This leads to different types of angulation osteotomies based on mainly the evaluation of the X rays

CLINICAL MANAGEMENT AND REPORTED RESULTS

To achieve a reduction of compressive forces upon the joint Pauwels stated that a release of musculature acting on the joint should be performed. Moreover a procedure increasing the weight transmitting area of the articular surfaces which consequently should reduce the pressure per unit area in the joint should also be carried out. By an intertrochanteric osteotomy with upward and medial displacement of the femoral shaft as described by McMurray the adductors and iliopsoas muscles are claimed to relax and thus the reduction of muscular force on the joint is obtained. The weight transmitting area is however not changed and accordingly an additional procedure has to be done which entirely depends on the preoperative position of the femoral head. If on radiographs it is estimated that to increase the weight transmitting area it becomes necessary to turn the head medially an adduction osteotomy is performed. If however a lateral tilt of the head is required to increase the weight bearing area an abduction osteotomy is carried out. In both procedures internal fixation is made. In more than 400 osteotomies done according to the above principles Pauwels (1951–1963) found the results most reliable, permanent and in many cases surprisingly good.

Muller, Nissen, Harris and *Kirwan* among others reporting very good results advocate intertrochanteric osteotomy with internal fixation in cases of hip joint osteoarthritis. According to these authors post osteotomy radiological improvement has shown that osteotomy can produce arrest and partial healing of the disease. In consequence it was therefore suggested (*Nissen*) that osteotomy be carried out at a much earlier stage. This assumption has been substantiated by the investigation of *Harris* and *Kirwan* who compared the results of osteotomy in two series of patients the one having osteotomy early (58 years, at least 90 degrees flexion, no radiographic evidence of collapse of bone), the other late (65 years, flexion reduced to between 60 and 90 degrees without collapse of bone or 90 degrees flexion but some collapse of bone). They found that early osteotomy seldom fails to give relief of pain (95 per cent) and that in 70 per cent convincing evidence of regression indicating arrest of the arthritic process was obtained. Improved function of the joint followed this investigated and proved by *Shepard*.

During recent years the operative technique has varied. These has been

a discussion as to how the osteotomy should be performed The devices for internal fixation have also changed We have only recently adopted compression methods Certainly the procedure can be further improved

It is obvious that surgery when discussed in terms of redistributing acting mechanical forces does not consider all the pathoanatomical conditions that may be of importance However many of the reports mention not only freedom of pain and improved function but also effects on the postoperative radiographic appearance claiming that the osteoarthritic process in itself can be repaired It is often claimed that other than pure mechanical events follow osteotomies such as improved circulation and favourable metabolic effects

In trying a surgical procedure it is certainly important to justify the intervention by pathophysiological explanations but this is not enough to encourage the use of the method unless the results from a pure therapeutic *point of view* satisfy *the patient* In this *report* we have therefore restricted ourselves to see what we have accomplished clinically

In 1960 one of us (*Hirsch*) studied the results obtained in late osteoarthritis by intertrochanteric osteotomies Complete relief of pain was obtained in only 30 per cent but 80 per cent claimed an improvement The mobility of the hip joint did not increase and the radiographic appearance did not alter As other reports have mentioned good results both clinically and radiographically we thought it necessary to reconsider the problem and therefore we carried out a follow up examination of osteotomized patients from 1961 through 1965 Our main interest was centered on the following questions

Age at onset of disease

Age at osteotomy

Functional and sociomedical disturbances preoperatively

Type of internal fixation of osteotomy and its influence on the postoperative process

The influence of the time for postoperative mobilization on end result

Complications with regard to type of internal fixation

Overall end results of osteotomy

pain

mobility

walking

work capacity

radiographic appearance

PRESENTATION OF MATERIAL

Age Distribution and Joint Affections

The material for this investigation consisted of 114 operated patients during the years 1961–1965. The 114 patients represented 123 operated hip joints. Of these 102 were personally investigated by either one of us during 1966–1967.

Table 1. Operated hip joints

Operated hip joint	Male	Female	Total
Right	24	36	60
Left	28	35	63
Total	52	71	123
Both	3	6	

In 6 females and 3 males both hip joints were operated. As is noticed there is an overrepresentation for females, 58 per cent compared to 42 per cent for the males but the distribution of side is fairly equal.

The distribution of age and sex (Table 2) in this material follows what is commonly reported in the literature (*McMurray, Gade, Pauwels, Harris* and *Kirwan, Milch, Tillberg*). The ages varied from 40 to 78 years with an average of 59.6 years for the males and 53.1 years for the females.

Table 2. Distribution of age and sex of patients at time for osteotomy

Age	Male	Female	Total
40–50	10	12	22
50–60	21	20	41
60–70	20	18	38
70–80	3	10	13
Total	54	60	114

The age at which the first symptoms appeared in the patients is shown in Table 3.

The predominance for females in the younger age periods is noted. As is seen in Tables 2 and 3 the material contains patients with early

osteoarthritis which from the point of view of age can be well compared with the cases of early arthritis reported by *Harris* and *Kirwan* in whose early group the average age was 58 years and in the late group 65 The length of history before operation was also ascribed some importance by *Harris* and *Kirwan* who found that for the early group it was 4 years and 9 months and for the late 6 years and 3 months In our series the length of history before operation was three and a half years for the 40–50 year group six and a half to seven years for the 50–60 year group and about ten years for the 60–70 year group

Table 3 Period of age for appearance of symptoms

Age	Male	Female	Total
40 50	11	19	30
50–60	30	34	64
60 70	13	7	20
Total	54	60	114

All patients in this material presented osteoarthritis which in 91 patients was primary and in the remaining secondary to other structural joint abnormalities (Table 4)

Table 4 Structural joint changes prior to osteoarthritis

Structural change	Male	Female	Total
Congenital dislocation	1	11	12
Dysplasia	1	3	4
Perthes disease	2	–	2
Epiphyseolysis	1	1	2
Trauma	1	2	3
Total	6	17	23

COURSE OF DISEASE

The history of most patients was rather uniform though two definite types could be detected One was a group of patients who had continuous suffering with constant weight bearing pain and pain at rest They amounted to 72 The other group had considerable suffering though of an intermittent type with short periods of alleviation This was en

countered in 42 patients The daily activities of most patients were strongly limited due to the considerable pain which in many cases did not recede despite rest and analgesics In 16 patients however some form of activity was necessary for the alleviation of pain the most common being continuous flexion movements in the affected hip-joint Most patients experienced pain on standing walking, sitting and lying in bed Prior to osteotomy hospital admission for various types of therapy—including operative—had been necessary for 31 patients of which no less than 15 had been subjected to such surgical measures (Table 5)

Table 5 Types of surgical procedure in hip joints prior to osteotomy

Surgical procedure	Male	Female	Total
Voss operation	2	3	5
Exaeresis of obturator nerve	2	5	7
Coagulation of vessels and nerves	1	–	1
Osteomyelotomy	–	2	2
Total	5	10	15

Long term stays in convalescent homes were common and previous surgery had in all instances been followed by conservative treatment like that which patients had received who had not undergone surgery such as physio therapy (88 patients) baths (37) X ray treatments (57) intraarticular injections (44) and medicines of various types Of these acetylsalicylic acid was the most common (97 patients) and generally formed the basic drug which was supplemented periodically by other adjuvants such as morphine and derivatives (10 patients) muscle relaxants (10) antiphlogistic agents (17) and sedatives (8)

As the sick history of all patients had lasted for some years before the osteotomy they had had time to adjust themselves to the ailment and the limitations it imposed on their mobility and daily activities The condition immediately prior to operation was in general good 109 patients could look after themselves and partake in easier home life activities without too great difficulty The work capacity on the other hand was very limited and at the time of operation only 33 were fully at work

OPERATIVE PROCEDURE AND POSTOPERATIVE COURSE

Number of Osteotomies and Methods

The operative method was mostly an intertrochanteric osteotomy with internal fixation according to *Kessel, Tupman Blount* or *Wainright* respectively In some cases no internal fixation was used The number of osteotomies and choice of method are represented in Table 6

Table 6 Osteotomies during 1961–65 and choice of method

Year	Choice of method										Total
	Kessel		Tupman		Blount		Wainright		Other		
	M	F	M	F	M	F	M	F	M	F	
1961	–	1	3	4	1	–	3	9	–	–	21
1962	3	2	9	4	–	1	6	4	2	–	31
1963	–	2	2	3	1	1	9	9	–	–	27
1964	–	–	1	–	–	–	7	21	–	–	29
1965	–	–	–	2	–	–	7	6	–	–	15
Total	3	5	15	13	2	2	32	49	2	–	123

M = male F = female

Incision

As for the soft tissue technique a few variations were employed the importance of which became evident in the immediate postoperative course The incision was in most cases (116) directed obliquely from the anterior superior iliac spine to the trochanter and then continued distally for some 15 cm In the remaining seven a straight vertical incision above and below the trochanter was used The tensor fasciae latae was in all cases incised along the fibre direction and then cut at a right angle below the greater trochanter to release tension The vastus lateralis was in 23 cases dissected free from its origin at the greater trochanter and gently pushed anteriorly In 73 cases the same muscle was split in the middle along the fibre direction No information was given as to muscular incision in the remaining 27 operations

Osteotomy

The osteotomy was performed above the lesser trochanter in 111 cases right through it in 5 and below in 7 The shaft of the femur was dis

placed medialward The degree of medial displacement as judged by radiographs was 2 ± 0 5 cm

The instruments by which the osteotomies were carried out varied but on further investigation it did not become evident that either procedure had any influence on healing stability contact of resection areas or later course It was for some time thought that the use of a high speed electric saw might cause a necrosis of bone due to the emission of heat but this could in no way be proved In 13 cases an ordinary chisel was used in 91 an electric saw and in 19 a Gigli saw

Fixation

It was thought very important at the time of operation to achieve as stable a fixation and as good a bone contact as possible In 95 cases the fixation was considered stable in 4 rather dubious and in 2 very bad Information about the remaining 22 is lacking The two cases with bad fixation healed completely in due course In these series compression devices were not applied

The osteotomy contact was good in 90 cases acceptable in 29 and bad in 4 In two of these in which the contact was bad pseudarthrosis developed but on the other hand delay in union (see Table 15) occurred in cases where the surgical procedure was thought to be adequate

Postoperative Immobilization

The postoperative immobilization was in the beginning of the period very rigid with the patients in a hip spica for some 4–6 weeks This was used in 25 patients The remainder only had a plow in bed abducting their legs The time in bed postoperatively differed greatly depending on varying opinions on early activity The mean value of number of days spent in bed was 18 1 ± 10 5 The standard deviation is no doubt great but easily explicable by the fact that it was believed that the stable fixation and good osteotomy contact were sufficient to justify early rising from bed As will be noticed in the paragraph on complications this policy was not remunerative in the long run

Mobilization

Postoperative mobiliation *i e* walking exercises after termination of bedrest was carried out in different stages the first being walking without weight bearing on crutches the second weight bearing with

crutches and finally the third free walking The mean value in days of the first period was 16 8 ± 2 4 Those patients who no longer needed crutches or canes postoperatively stopped using them about the fifth month postoperatively

Postoperative Complications

Immediate complications postoperatively were clinically manifested thrombosis and wound infection The criteria for the former group were elevated pulse rate and temperature and calf tenderness for the latter group discharge from the wound with positive bacterial growth on culture The observations are listed in Table 7 and divided into groups according to method used

Table 7 Immediate postoperative complications

Complication	Kessel = 8	Tupman = 28	Blount = 4	Wainright = 81	Other = 2	Total = 123
Clinically manifested thrombosis	–	7	–	25	1	33
Infection	2	3	–	6	1	12

Because of the different sizes of the groups representing various fixation techniques a comparison of the frequencies becomes futile Certain conditions predisposing to thrombosis may however be mentioned *e g* age and nutritional state of patient technique of incision and the surgical wound behaviour postoperative haematomas type of immobilization time for institution of and energy of physiotherapy period of bedrest and preoperative use of anticoagulants In our series we noted a slight tendency to high thrombosis frequency in those cases where the vastus lateralis had been split lengthwise through the muscle mass Thrombosis was also met frequently in those patients who were postoperatively immobilized in plaster The observations however are made on too small a material to become significant but may nevertheless serve as a possible explanation for the formation of thrombosis The rate of infection is higher than is commonly seen in a surgically treated material but the true culprit besides the bacteria is difficult to pursue Most of these followed an innocent course excepting one patient who died from general sepsis

FOLLOW UP

The follow up was carried out during 1966 and 1967 thus with a longest observation time of 5 years and a shortest of 18 months Of the 114 operated patients 102 were followed up 12 could not be examined for various reasons as seen in Table 8 Each patient was personally approached by one of us and questioned according to a special questionnaire and also physically examined The number of followed up hips was 110 as seen in Table 9

Table 8 Reasons for exempted follow up

Reason	Male	Female	Total
Death			5
Cancer	1	–	
Circulation	1	2	
Postop sepsis	1	–	
Living abroad	1	–	1
Not traced	1	2	3
Refusal to present at follow up	1	2	3
Total	6	6	12

Table 9 Followed up hip joints after osteotomy

Operated hip joint	Male	Female	Total
Right	21	33	54
Left	25	31	56
Total	46	64	110

12 patients representing 13 hip joints have not been followed up

Table 10 Spontaneous pain

	Male	Female	Total
Improved	40	45	85
Unchanged	1	4	5
Deteriorated	5	7	12
Total	46	56	102

Table 11 Weight bearing pain

	Male	Female	Total
Improved	33	38	71
Unchanged	5	11	16
Deteriorated	8	7	1
Total	46	56	102

The relevant questions for the follow up in this investigation were a) spontaneous pain b) weight bearing pain c) mobility from subjective and objective points of view d) walking capacity e) work capacity and f) general subjective evaluation

Mobility

This was indicated in two ways the first being the patient s subjective evaluation of his postoperative mobility Great importance was paid to the patient s own estimation of his ability to put on and take off shoes to tie shoestrings to put on stockings to sit comfortably both at home and in cars and finally to climb tramcars and buses The results are seen in Table 12

Table 12 Subjective evaluation of postoperative hip joint mobility

	Male	Female	Total
Improved	21	16	37
Unchanged	6	20	26
Deteriorated	17	22	39
Total	44	58	102

The second way of approach was an objective estimation of the difference in mobility before operation and after operation At this investigation the length of the lower limb was measured The following variables were thus studied and the values before and after operation compared length of lower limb flexion adduction abduction outward rotation and space inward rotation The distribution of frequency for each quality is seen in Figures 1–7

The values have been subjected to statistical analysis according to Student s t test The test has been carried out on the 5 per cent level

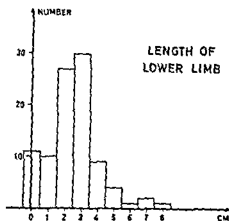


Fig 1

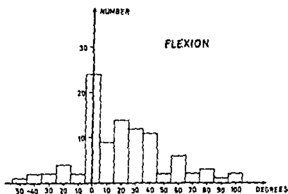


Fig 2

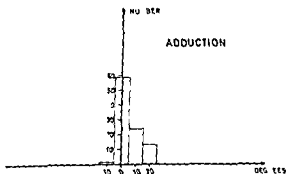


Fig 3

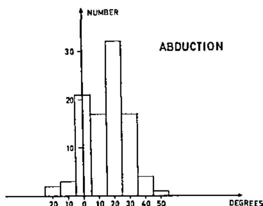


Fig 4

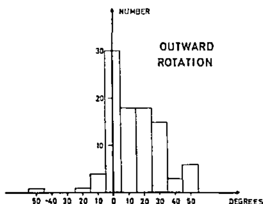


Fig 5

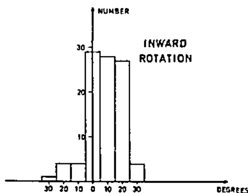


Fig 6

Summarizing the analysis it can thus be said that the difference of values before and after operation are significantly greater than zero i e all variables show less values after operation On the 5 per cent level the following results were obtained

Length of lower limb difference is between	2 and	3 cm	See Figure 1
Flexion	10	20	„ 2
Adduction	0	5	3
Abduction	10	20	4
Outward rotation	10	20	5
Inward rotation	0	10	6

Walking Capacity

This was mostly dependent on the use of a cane Therefore it was thought appropriate to estimate the ability for walking in correlation to the use of the cane pre and postoperatively as shown in Table 13

Table 13 Walking capacity as related to the use of cane

	Before operation	After operation	
		with cane	without cane
Use of cane	65	55	10
No use of cane	42	25	17

In judging the walking ability of osteotomized patients it soon becomes evident that the true nature of their gait is not disclosed unless a very penetrating interrogation is tactfully carried out To many the use of a cane becomes such an ingrown habit that walking with it is not looked upon as an aid to facilitate each individual step On attempting to walk without a stick the patient however becomes aware of the difficulties her gait then gives her The most common factors met in this material were the weightbearing pain and the limp secondary to the shortening of the lower limb Indoor walking was easier than outdoors and on interrogation it was found that the patients generally walked with the aid of chairs tables and other objects in the home which could give some support It was surprising to find how many patients (32) had a scheduled route to follow on moving from one part of the home to the other

Work Capacity

On perusing the material in general the following results were obtained Table 14 which is a rough estimate of the patients own opinion of their capacity to carry out work with which they had preoperatively been occupied or a new occupation into which they had been introduced postoperatively

Table 14 Work capacity

	Male	Female	Total
Improved	15	21	36
Unchanged	10	22	32
Deteriorated	19	15	34
Total	44	58	102

Complications

The complications met in the later postoperative course were pseudarthrosis and fracture of the instrument for internal fixation Table 15

Table 15 Late postoperative complications

Complication	Kessel = 8	Tupman = 28	Blount = 4	Wainright = 81	Other = 2	Total = 123
Pseudarthrosis	1	3	1	11	–	16
Fracture of fixation instrument	2	2	–	3	–	7

The rate of pseudarthrosis seems at least partly to be related to the length of postoperative stay in bed

Thirteen of the total 16 pseudarthrosis cases had postoperative immobilization in bed of considerably shorter duration than the mean average This was estimated at 18 1 days with a deviation of ± 10 5 days The thirteen pseudarthrosis cases remained in bed for 9–12 days

All pseudarthrosis cases were reoperated In ten of these the non united area was bonegrafted In the remainder the area was drilled Fifteen have healed completely whereas one despite bonegrafting remained nonunited

The fractures of the fixation instrument were interpreted as metal

fatigue Some patients whose osteotomies had satisfactorily healed experienced pain of another type than that of osteoarthritis It became evident that the internal fixation instrument could cause discomfort and therefore the fixation material was extracted in a number of cases as seen in Table 16

Table 16 Extraction of fixation instruments due to pain

Kessel = 8	Tupman = 28	Blount = 4	Wainright = 81	Total = 123
3	14	1	14	32

All these patients were relieved of their pain after extraction

Subjective Evaluation

How the patients experience the operation and how they appreciate their postoperative condition is seen in Table 17

Table 17 Subjective evaluation of postoperative condition

	Male	Female	Total
Satisfied	38	43	81
Not satisfied	15	6	21
Total	53	49	102

Thus the great majority was satisfied with the results of the operation despite weightbearing pain certain limitation in daily activities minor decrease in mobility and limp on the operated side On further analysis it became evident however that the greatest appreciation was due to the abolition of spontaneous pain The patients could enjoy a night s good sleep without being disturbed by pain and sitting was no longer an obstacle in social life The appreciation of this was so great that other discomforts secondary to operation were almost ignored

Radiographic Appearances

We have tried to evaluate the radiographs The pictures vary to a great extent and there is very little correspondence between what could be

seen on X-ray and the clinical results Rarely did the joint space increase nor did sclerosis or cystic formations disappear

SUMMARY

On 114 patients with osteoarthritis of the hip joints 123 hips were operated with intertrochanteric displacement osteotomy and internal fixation according to Kessel Tupman Blount or Wainright

A follow up was carried out 18 months—5 years following surgery in 102 patients representing 110 hips Good results were obtained in 82 3 per cent The improvement was most pronounced in patients with constant pain at rest

Weight bearing pain was diminished in 72 5 per cent but a majority had to use a cane postoperatively

The mobility had improved or remained unchanged in 64 7 per cent but deteriorated in 38 2 per cent

Pseudarthrosis was encountered in 13 per cent and all have been reoperated with a good result excepting one patient

The technique used ended with the neck of the femur in varus Shortening of the lower limb was seen in all patients and experienced as great discomfort

It is felt that improved internal fixation offering more accurate and reliable fixation should decrease the rate of pseudarthrosis and unexpected positions

RESUME

Chez 114 malades souffrant d ostéoarthrite de l articulation de la hanche 123 hanches ont été operees par déplacement intertrochanterique ostéotomie et fixation interne selon Kessel Tupman Blount et Wainright

Un réexamen a été pratiqué entre 18 mois et 5 ans après l intervention chirurgicale chez 102 malades représentant 110 hanches De bons résultats avaient été obtenus dans 82 3 pour cent des cas L amélioration a été la plus marquée chez les malades qui avaient des douleurs constantes même au repos

La douleur provenant du port du poids du corps a ete diminuee chez 72 5 pour cent mais une majorité des malades ont été obliges de se servir d une canne après l opération

La mobilité s est accrue ou est restée inchangée dans 64 7 pour cent

des cas mais elle a été diminuée dans 38 2 pour cent On a rencontré une pseudarthrose dans 13 pour cent et tous ces cas ont été reopérés avec un bon resultat à l exception d un seul malade

La technique utilisée a abouti au placement en varus du col du fémur Un raccourcissement du membre inférieur a été constaté chez tous les malades ce qui est ressenti comme un grave inconvénient

On a l impression qu une fixation interne améliorée comportant une fixation plus minutieuse et plus stable devrait pouvoir diminuer le nombre des pseudarthroses et les positions inattendues

ZUSAMMENFASSUNG

Bei 114 Patienten mit *Arthrosis deformans der Huftgelenke* wurden 123 Hüften mittels intertrochanterer Verschiebungsosteotomie und interner Fixierung nach *Kessel, Tupman, Blount* und *Wainright* operiert

*Eine Nachuntersuchung wurde 18 Monate bis 5 Jahre nach der Opera*tion an 102 Patienten mit 110 Huften durchgefuhrt Gute Ergebnisse wurden in 82 4 Prozent erhalten Die Besserung war am meistem bei *Patienten mit konstanten Ruheschmerzen ausgesprochen*

Belastungsschmerzen waren bei 72 5 Prozent verringert aber die Mehrheit musste nach der Operation einen Stock gebrauchen

Die Beweglichkeit war in 64 7 Prozent gebessert oder unverändert geblieben war jedoch in 38 2 Prozent verschlechtert

Pseudarthrose wurde bei 13 Prozent angetroffen und alle diese wur*den abgesehen von einem mit gutem Ergebnis reoperiert*

Die verwendete Technik endete mit dem Schenkelhals in Varusstellung Verkurzung der unteren Gliedmasse wurde bei allen Patienten *beobachtet und wurde als eine grosse Belästigung empfunden*

Man ist der Meinung dass eine verbesserte interne Fixation die eine genauere und verlässlichere Ruhigstellung darbietet das Vorkommen *von Pseudarthrosen und unerwarteten* Stellungen herabsetzen sollte

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ACTIVE-EXTENSION CAPACITY OF THE KNEE JOINT IN THE HEALTHY SUBJECT

By

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Received 14 i 67

It is usually assumed that a person in good sound health can actively extend the knee joint through the full range with the possible reservation of a slight resilience due to stretching of the posterior articular capsule if a powerful attempt is made to extend the joint passively In earlier papers the authors have examined the forces acting in the knee-joint in active extension (2) and measured the force exerted by the quadriceps in the healthy subject (3) It was found that near full extension it was difficult if not impossible to obtain a reliable determination of the position of the knee joint by ordinary clinical methods and it was necessary to resort to radiographic examination

In connection with these studies it was found surprisingly enough that healthy subjects in the supine position with the leg raised from the table were unable to extend the knee joint fully In passive extension with the foot supported and the leg hanging freely and relaxed there was a further 5 of extension on average and in some cases as much as 10 With the object of further examining this active extension defect we have carried out a more systematic study on a series of knee joints

MATERIAL

The study was performed on 52 subjects with sound knees some of them hospital staff and others patients admitted for disorders not concerned with the lower extremities The age and sex distribution is shown in Table 1 The term "sound knee" as used here implies that the knee joint was clinically normal, that there were no symptoms associated with the knee and that a radiographic examination of the joint did not disclose pathologic alterations apart from mild arthrosis.

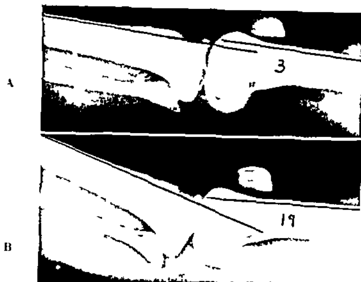


Figure 1. The knee joint in lateral view. The reference lines for the femur and tibia are drawn in. A. Full passive extension (zero position). B. Full passive extension with the leg horizontal. In this case the active extension defect was unusually large (16°) and was obvious on clinical investigation.

METHODS

The extension position of the knee joint was determined on X-ray films. Lateral projections were taken with a focus to film distance of 100 cm. As a reference line the anterior contour of the femur or tibia was used (Figure 1). Maximum extension (the reference position) in this connection is defined as the position obtained with the patient supine and the leg horizontal with a support under the foot and a load of 5 kg over the knee joint. The degree of flexion was measured from this reference position.

The following positions of the knee joint were examined:

(1) Supine with the leg relaxed and supported under the foot with a load of 5 kg applied over the knee joint (the weight was hung in a sling).
(2) Supine as in (1) but with a weight of 3 kg.
(3) Supine as in (1) but with a weight of 1 kg.
(4) Supine as in (1). Fully relaxed but with no load.
(5) Supine but with full active extension of the knee which is raised from the table unsupported. When the exposure was made the patient was asked to extend the knee joint as much as possible.
(6) Standing with full active extension of the knee unsupported.

In a further 14 subjects 7 and 9 kg loads were used to see whether there would be further extension beyond the reference position.

Table 1 Distribution of subjects with respect to age and sex

Age	20 29	30–39	40–49	50–59	50–59	60–69	Total
Men	1	5	3	13	9	1	32
Women	1	5	2	5	2	5	20
Total	2	10	5	18	11	6	52

Table 2 Flexion of the knee joint in various positions in a comparison with full extension defined as the position with a load of 5 kg over the knee joint and the muscles relaxed

	Flexion ( )	
	Mean	Range
Supine relaxed Load 5 kg	0	
Supine relaxed Load 3 kg	0.6	−1 to +3
Supine relaxed Load 1 kg	1.1	−1 to +4
Supine relaxed. Load 0 kg	2.4	+1 to +5
Active extension standing	3.9	+1 to +7
Active extension supine	5.1	0 to +19

RESULTS

The mean flexion and the ranges for the various positions are presented in Table 2 A reduction of the load on the knee from 5 to 3 kg gave extremely little flexion The difference was not significant With a load of 1 kg there was slight flexion that was significantly different from the reference position ( ) the effect was still more pronounced with no load at all

In the 10 cases loaded with 7 and 9 kg there was on average an extremely small additional extension (not significant)

In full active extension in the erect position there was a mean flexion of 3.9 and in full active extension in the supine position (when the weight of the lower leg contributes to the flexion) the flexion position was still greater—on average 5.1 the differences were significant ( ) It is remarkable that in several subjects the active extension defect in the supine position was more than 10 and in one case as much as 19 it was then possible even with the ordinary clinical methods to see that full active extension was not achieved

DISCUSSION

The earlier observation that active extension of the knee could not always be achieved completely in the supine position with the leg raised was verified by this study. What are the causes of this relative insufficiency? In earlier studies by *Lindahl & Movin* (2) and *Hallén & Lindahl* (1) on the forces acting in the knee joint in extension and on the causes of active extension defects in various knee injuries, it was found that the lever action of quadriceps at terminal extension became increasing less favourable. As it is known that a muscle exerts a lower force within its inner path of contraction (von Schwanns's law), these two facts would explain the difficulty of obtaining full active extension. In active extension in the supine position with the leg raised from the table the weight of the lower leg acts in the direction of flexion, and this may contribute to the extension defect. In the same test in the vertical position this weight does not act, and the tone and elasticity of the flexor muscles will then possibly be the only residual factor that counteracts full extension. An impression of the magnitude of this flexing force is obtained from the change in extension achieved with different loads in the supine position with the knee supported but relaxed: practically full extension could be obtained with as small a load as 3 kg, while a load of 1 kg did not suffice to overcome the resistance due to the tone and elasticity of the flexors.

The difference of 2 kg is enough to overcome the tone and elasticity of the flexors and represents a supplementary force of the order of 40 kgf cm[1] acting as a moment (the distance from the knee to the points of support in the proximal and distal direction is assumed to be about 40 cm). The difference in the moment required to obtain full active extension in the horizontal and erect positions is, for a normal person, on average 100 kgf cm; this value, which may be ascribed to the weight of the lower leg, gives an impression of the magnitude of the force that the quadriceps can *not* exert in extension. With, for instance, a flexion of 120°, the quadriceps in the sound knee develops on average a moment of 2200 kgf cm; from these measurements it may be concluded that the muscular power of the quadriceps in extension is about *one twentieth* of that in flexion, and if account is taken of the unfavourable lever action in extension, the absolute force for the quadriceps in extension will be only about one fifteenth of that in the 120° position.

There were large individual differences in the recorded values: *for 9*

[1] kgf = kp = 9.81 newtons ≈ 2.2 pounds weight

out of 52 subjects the active extension defect was only 1 or 0 In these cases there was thus no active extension defect of practical significance and then the power exerted by the quadriceps in extension is presumably much greater This individual variation may account for the relative ease with which some subjects could perform full extension in quadriceps exercise after knee injuries or operations

SUMMARY

Fifty two normal knee joints were examined by radiography to determine accurately the position of the joint *in full active extension* compared with various positions of passive extension There was a mean of active extension defect of 5 1 in the knee joint compared with a passive extension obtained by loading the joint with 3–5 kg and supporting the foot It is concluded that the power of the quadriceps for further extension in positions of extension is too low (less than 100 kgf cm) to overcome the resistance presented by the tone and elasticity of the flexors

RESUME

Cinquante deux articulations normales du genou ont été examinées par radiographie pour déterminer avec précision la position de l'articulation *en pleine extension active* par comparaison avec des positions variées d'extension passive Il y avait une extension active défectueuse de 5 1 en moyenne dans l'articulation du genou comparée à l'extension passive obtenue par une charge de 3 à 5 kg sur l'articulation ayant aussi à supporter le poids du pied On en conclut que la puissance du quadriceps pour une plus grande extension dans les positions d'extension est trop faible (inférieure à 100 kgf cm[1]) pour affronter la résistance opposée par le tonus et l'élasticité des fléchisseurs

ZUSAMMENFASSUNG

Zweiundfünfzig normale Kniegelenke wurden mittels Röntgenstrahlen untersucht um die genaue Position des Gelenkes *bei voller aktiver Streckung* verglichen mit verschiedenen Positionen bei passiver Streckung zu vergleichen Man fandt einen durchschnittlichen aktiven Streckdefekt von 5 1 im Vergleich mit einer passiven Streckung die man erhielt wenn man das Gelenk mit 3 5 kg belastete und den Fuss unter

[1] kgf = kp = 9 81 newtons = 7 2 pounds de [illegible]

stutzte Man schliesst daraus dass die Kraft des Quadriceps für di weitere Streckung in Streckpositionen zu gering ist (weniger als 10 kgf cm[1]) um den Widerstand der vom Tonus und der Elastizitet de Flexoren ausgeubt wird zu uberwinden

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1 kgf = kp = 9 81 Newtons = 2 2 Pfund Gewicht

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HAEMANGIOMA OF THE KNEE JOINT

By

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Received 4 xii 66

Haemangiomas are vascular malformations which usually develop during early childhood They are fairly common on the limbs but seldom involve the joints

According to their situation the haemangiomas affecting the region of the knee may be divided into juxta articular situated outside the joint capsule but in relation to it intra articular situated within the joint capsule and intermediate which are of an intra as well as extra articular situation (7 10) The intra articular and intermediate haemangiomas generally involve the synovial membrane

The first case of synovial haemangioma was described by *Bouchut* in 1856 (5) In 1939 *Bennett & Cobey* (2) on the basis of the 29 cases published up till then could distinguish between two types of synovial haemangioma diffuse and circumscribed The diffuse type usually consisted in a cavernous haemangioma giving rise to the typical intermittent pain and swelling in the joint Circumscribed haemangiomas were often in the form of a pedunculated synovial tumour and of the capillary type Episodes of locking were characteristic In 1959 *Lewis Coventry & Soule* (9) published 11 cases treated in the Mayo Clinic during the period 1907 to 1956 Their findings confirmed in all essentials *Bennett & Cobey's* The total number of published cases now numbered 58

Since that time another 17 synovial haemangiomas have been reported (1 6 7 8 10-17) bringing the total up to 75 Of these haemangiomas 1 affected the elbow joint one the ankle joint (9) while the remaining 73 were situated in or at the knee joint

It is the object of the present paper to report another 7 cases of synovial haemangioma in the knee joint and 12 cases of juxta articular

haemangioma at the same joint The symptoms and signs in the two groups the differential diagnosis and the treatment will be discussed

MATERIAL

During the period 1937 to 1966 operations were performed on 19 haemangiomas in the region of the knee

In 7 cases the haemangioma involved the synovial membrane In one of these cases the haemangioma was intra articular and in 6 cases intermediate

In 12 cases the haemangioma was juxta articular

Out of the 7 synovial haemangiomas 4 were found in females and 3 in males Out of the 12 juxta articular ones 3 affected females and 9 males

Table 1 gives the patients ages at the first symptom It will be seen that the complaints started with almost equal frequency all through childhood However 3 of the juxta articular haemangiomas did not give rise to symptoms until the patients were 16 30 and 44 years of age

Table 1 Age at onset of symptomes in 19 cases of knee joint haemangioma

	Total number of cases	<1 year	1–5 years	6–10 years	11–15 years	>15 years
Synovial haemangioma	7	2	1	2	2	0
Juxta articular haemangioma	12	1	2	4	2	3

Table 2 The clinical features of knee joint haemangioma

	Total number of cases	Mean duration of symptoms when first seen	History of trauma	Pain and swelling	Intermittent symptoms	Locking
Synovial haemangioma	7	4 years	2	7	[illegible]	1
Juxta articular haemangioma	12	3 years	3	8	8	1

From Table 2 it is apparent that the nature of the symptoms was approximately the same whether or not the haemangiomas involved the synovial membrane and in both groups the patients had been suffering from the symptoms for an average of 3–4 years when they were referred to us It must be mentioned however that intermittent pain and swelling in the joint were present in nearly all the synovial haemangiomas while these symptoms were less common in the juxta articular haemangiomas Two patients had a history of locking One proved to have a diffuse

synovial haemangioma the other one a juxta articular haemangioma localized beneath the vastus medialis The aetiology of the locking is obscure

The physical signs are listed in Table 3 In 2 of the synovial haemangiomas there was swelling of the joint which was never present in juxta articular haemangiomas. In addition pain and limited mobility were considerably more common in synovial haemangiomas In the only case where a juxta articular haemangioma gave rise to limited motion there was a question of a large haemangioma in the vastus medialis and this caused a moderate restriction of flexion Of the 4 cases where a synovial haemangioma restricted the mobility this restriction was moderate in 3 cases while in one it was pronounced owing to violent destructive osteoarthritis in the joint. Muscular atrophy was also a relatively common finding in synovial haemangioma In most of the patients a mass was palpable in the region of the knee As a rule the masses were soft and ill defined Among the synovial haemangiomas a palpable mass was present in 4 Two of these masses were tender In juxta articular haemangioma there was a palpable mass in 8 3 were tender In 3 instances the tenderness was not present especially on a level with the mass being more diffuse in the region of the knee

Table 3 The physical signs of knee joint haemangioma

	Total number of cases	Joint swelling	Pain on motion	Limitation of motion	Mass	Tenderness	Muscle atrophy	Haemangioma elsewhere	Leg length discrepancy
Synovial haemangioma	7	2	5	4	4	4	5	3	1
Juxta articular haemangioma	12	0	6	1	8	4	4	2	2

X ray examination in 7 cases of synovial haemangioma revealed in 2 phleboliths In one of these cases there was also destruction of the point, particularly marked in the medial tibial condyle (Figure 1) In one case there was a translucency in a femoral condyle and in one case there was periosteal reaction distally on the femur Among the 12 juxta articular haemangiomas there were phleboliths and periosteal reaction distally on the femur in one (Figure 2) destructive changes in a tibial condyle in one and periosteal reaction distally on the femur in one

At operation the haemangioma was in all 7 cases localized at the site of the named radiographic changes

Arteriography was performed in 6 cases In 3 it revealed haemangioma in the knee region and in one also arteriovenous anastomosis in the same region

Phlebography was carried out in 2 cases In one it showed intra articular haemangioma (Figure 3)

In the present series the diagnosis was made preoperatively in 3 out of the 7 cases of synovial haemangioma and in 4 out of 12 cases of juxta articular haemangioma

Operation disclosed 7 synovial haemangiomas, one of which was in the form of a



Figure 1. Synovial haemangioma with phleboliths and joint destruction.
Figure 2. Juxta-articular haemangioma with phleboliths and periosteal reaction.
Figure 3. Phlebography of intra-articular haemangioma.

circumscribed intra-articular non-pedunculated synovial tumour, while 6 were intermediate haemangiomas of the diffuse type penetrating the joint capsule and spreading without any sharp demarcation into the surrounding tissue. In 4 cases they involved the quadriceps muscle, in 2 only the skin and subcutaneous tissue. While the circumscribed haemangioma could be removed radically without any difficulty, this was not possible in the case of the 6 diffuse ones. In one of these cases there was violent destruction of the joint and arthrodesis was performed.

Operation disclosed 12 juxta-articular haemangiomas in an extra-articular situation but in relation to the knee joint capsule. 7 of these haemangiomas were circumscribed while 5 were diffuse. Out of the diffuse haemangiomas 3 involved the quadriceps muscle, 1 the popliteal bursa and 1 exclusively the subcutis. In this group too radical surgery was possible only in the case of circumscribed haemangiomas.

On pathological examination 5 out of the 7 synovial haemangiomas including the circumscribed one could be classified as cavernous, 1 was capillary and 1 a fibro-haemangiomas cavernosum. Out of the 12 juxta-articular haemangiomas 11 were examined histologically and all were found to be of the cavernous type.

The postoperative follow-up period for synovial haemangiomas ranges from 3 months to 12 years, average 3 years. There have been two recurrences. One occurred about 10 years after the operation and was reoperated with a good result. The other recurrence appeared 4 years after the operation and was treated with X-rays. The patient has now been symptom free for [illegible] years.

The juxta-articular haemangiomas have usually been followed for only a few months after the operation so that it is not possible to assess the recurrence rate.

DISCUSSION

Synovial as well as juxta articular haemangiomas are rare and this is no doubt the explanation why they are so seldom diagnosed pre operatively in spite of the characteristic syndrome In the present material for instance synovial haemangiomas were diagnosed pre operatively in only 3 out of 7 cases and in *Lewis Coventry & Soule s* series in 3 out of 11 cases (9)

With the present material the total number of published cases of synovial haemangiomas is brought up to 82 It is worth noting that in 80 of these cases the haemangioma has affected the knee joint

The typical patient with synovial haemangioma is a child who has for some years had intermittent pain and swelling of a knee joint The symptoms are usually not preceded by trauma In most cases a soft diffuse and at times tender mass is palpable in the region of the knee As a rule there is pain on moving the joint and often a somewhat restricted mobility Muscle atrophy is a common finding Not infrequently there are haemangiomas of the skin in other sites X ray examination occasionally shows phleboliths and possibly destructive changes or periosteal reaction of the bone at the site of the haemangioma Articular destruction also occurs

The symptoms and signs of juxta articular haemangioma do not differ much from the above description and often the differential diagnosis with a view to the localization of the haemangioma in relation to the synovial membrane causes difficulties If there is swelling in the joint and in particular if joint puncture yields blood the haemangioma of course involves the synovial membrane In the event of considerably restricted motion and muscle atrophy there is presumably also a question of synovial haemangioma Otherwise the only means of determining the accurate site of the haemangioma in fairly early cases is arteriography or phlebography

If there is an arteriovenous shunt in connection with the haemangioma the limb on the affected side may be lengthened and the symptoms and signs on the whole characterized by the increased arterio venous flow It is of the utmost importance to diagnose such shunts preoperatively Therefore arteriography should invariably be done if there is a suspicion of haemangioma Plethysmographic investigation too will frequently afford valuable preoperative information (4)

In respect to the prognosis in untreated cases it is of essential importance that owing to the ever recurring haemorrhage in the joint

the synovial haemangioma may lead to considerable destruction in the joint similar to that seen in haemophiliac patients (2). The present material includes one such case in which the articular destruction was so advanced that arthrodesis had to be done.

Accordingly, the synovial haemangiomas should be treated at a stage as early as possible. In juxta-articular haemangiomas the indication is not quite so clear, and in the event of mild symptoms it may be justified to await spontaneous remission.

In circumscribed haemangiomas radical surgery is possible, and in these cases surgery gives good results (9). In diffuse haemangiomas radical operation is very difficult (2). The present material includes 11 haemangiomas of the diffuse type and none could be treated radically. In diffuse haemangiomas, therefore, X-ray irradiation is indicated postoperatively or as the only treatment (2, 3). In the present material one recurrence of synovial haemangioma was successfully treated by X-ray irradiation.

SUMMARY

During the period 1937 to 1966 a total of 19 cases of haemangioma in the region of the knee were treated by operation. 7 haemangiomas involved the synovial membrane. In 18 cases microscopic examination of the haemangiomas was done. One was classified as capillary, whereas the remainder were of the cavernous or predominantly cavernous type.

The typical symptoms and signs of synovial and juxta-articular haemangioma are described (Tables 1, 2 and 3).

In localized haemangiomas surgical treatment gives good results, but in the diffuse cases radical surgery is seldom possible. In such cases X-ray irradiation is used either postoperatively or as the only treatment.

RÉSUMÉ

Au cours de la période 1937 à 1966 un total de 19 cas d'hémangiome dans la région du genou ont été traités chirurgicalement. 7 hémangiomes atteignaient la membrane synoviale. Dans 18 cas il a été effectué un examen microscopique de l'hémangiome. L'un a été classifié comme capillaire alors que tous les autres étaient du type caverneux ou avec prédominance du type caverneux.

Les symptomes typiques et les signes d'hémangiome synovial et juxta-articulaire sont décrits (Tableaux 1, 2 et 3).

Lorsque l'hémangiome est localisé, le traitement chirurgical donne

de bons resultats mais dans les cas diffus une intervention radicale est rarement possible Dans ces cas on a recours a l irradiation aux rayons X soit apres l operation soit comme unique traitement

ZUSAMMENFASSUNG

Wahrend des Zeitraumes 1937 bis 1966 wurden insgesamt 19 Falle von Hæmangiom der Knieregion operativ behandelt 7 Hæmangiome um fassten die Synovialmembran In 18 Fallen wurde eine mikroskopische Untersuchung des Hæmangiomes vorgenommen Eines wurde als Kapillarhæmangiom klassifiziert wahrend die übrigen von kavernöser oder vorherrschend kavernöser Type waren

Die typischen Symptome und Zeichen von synovialen und juxta artikularen Hæmangiomen werden beschrieben (Tabelle 1 2 und 3)

Bei lokalisierten Hæmangiomen fuhrt die chirurgische Behandlung zu guten Ergebnissen in diffusen Fällen ist radikale Chirurgie jedoch nur selten möglich In solchen Fallen wird Röntgenbestrahlung ent weder postoperativ oder als alleinige Behandlung verwendet

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16 Skwarcz A (1960) A case of angioma of the knee joint *Chir Nar ad Ruchu Ortop Pol* 25 509
17 Stauber R (1957) Hemangioma of the prepatellar bursa *Zbl Chir* 82 1409
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From the Orthopaedic Hospital Aarhus Denmark
(Heads Professor E. Thomasen MD and J Saugmann-Jensen MD)

ARTHROGRAPHY IN MENISCAL INJURIES OF THE KNEE JOINT

By

JORGEN SOMMER

Received 18 xi 66

Meniscal injury is still a diagnostic problem and the value of arthrography as a supplementary diagnostic procedure in clinically doubtful cases is still a matter of discussion On the other hand it seems to be widely agreed that arthrography is unnecessary when the clinical diagnosis seems obvious

The object of the present study was (1) to investigate the accuracy of the arthrographic diagnosis in a material of clinically doubtful cases of meniscal injury and (2) to ascertain whether the diagnostic accuracy is altered by supplementing the clinical investigation by arthrography in clinically doubtful cases

PRESENT INVESTIGATIONS

In the Orthopaedic Hospital Aarhus Denmark operation is performed without previous arthrography if the clinical diagnosis is "certain i e the history and the physical findings make the diagnosis of meniscal injury very likely In clinically doubtful cases preoperative arthrography was performed up to 1963 but the operative indication was not based solely upon the arthrographic findings

The arthrographies were carried out in the Radiological Department of the Aarhus County Hospital and the reports from the radiologists formed the sole basis of whether the arthrographies were considered positive or negative A positive arthrography is taken to mean that the report indicates an injury or a suspicion of such injury A negative arthrography is taken to mean that according to the report the appearances are normal

During the period 1960–1962 arthrography was performed on 166

14 Rinaldi C. & Veneroni G (1960) Ossenazioni su di un caso di angioma del menisco del genocchio *Minerva ortop* 11 142

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From the Orthopaedic Hospital Aarhus Denmark
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ARTHROGRAPHY IN MENISCAL INJURIES OF THE KNEE JOINT

By

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Received 18 xi 66

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During the period 1960–1962 arthrography was performed on 166

patients in whom the clinical diagnosis was doubtful. Arthrographies carried out on other indications, e.g. a suspicion of a meniscal remnant left by previous meniscectomy, loose body or the like, were excluded.

Of these 166 patients 98 had operations. The preoperative arthrographic findings and operative results are shown in Table 1.

Table 1. Preoperative Arthrographic Findings Compared with the Operative Findings

Preoperative arthrographic finding	Number of cases	Operative finding: Injury	Operative finding: No injury	Percentage of arthrographic error
Injury	54	37	17	31
No injury	44	23	21	52

Table 2. Result of Follow Up on the Non Operated Patients Compared with the Arthrographic Findings

Arthrographic finding	Number of cases	Followed patients: Injury	Followed patients: No injury	Not followed
Injury	4		2	2
No injury	64	8	50	6

It will be seen that out of 54 positive arthrographies 17 were incorrect, i.e. a percentage of error of 31. Out of the negative arthrographies 23 of 44 were incorrect, a percentage of error of 52. Thus, in cases where it was possible to check the arthrography by operation, there was a total error in the preoperative arthrographic diagnosis of 40 per cent in cases of clinically doubtful meniscal injuries. It should be pointed out that the error is most pronounced in cases of negative arthrography.

Out of the remaining 68 who did not undergo operation 64 had nega… while 4 had positive arthrographic findings. Out of these 4 patients 1 refused to have an operation. The other 3 were asked to present themselves for operation but failed to come. Of the 68 patients 33 have been followed up for an average of 4 years (1 year 3 months to 6 years 6 months). Eighteen patients have been followed up for such a long time that according to the data in the records further follow up is not necessary. The average follow up period for these 18 patients is 18 months (6 months—4 years). Out of the remaining 17 I have been in touch with 9 by telephone or letter. All reported that they were symptom…

tion was based solely upon the arthrography however they found an error of 26 6 per cent Therefore their findings too cannot be taken to indicate that arthrography increases the diagnostic accuracy

CONCLUSION

It is obvious that the question whether the history and clinical findings indicate operation in the individual cases must vary appreciably from surgeon to surgeon Considering however the marked arthrographic error in clinically doubtful cases the only conclusion that can be drawn is that the arthrographic inaccuracy is as great as the clinical inaccuracy and that—as also demonstrated in the present study—the diagnostic accuracy is independent of whether or not arthrography is done pre operatively

SUMMARY

This is a report on a 3 year material comprising 166 patients with clini cally doubtful meniscal injuries who underwent arthrography The arthrographic findings were checked at operation or at follow up of the non-operated patients The accuracy of the arthrographic diagnosis is discussed

To ascertain whether the clinical diagnosis can be altered by doing preoperative arthrography in clinically doubtful cases two 2 year operative series were compared In one arthrography was done pre operatively in cases where the clinical findings were doubtful while in the other series no arthrography was done

It is concluded that the inaccuracy of the arthrography is as great as that of the clinical examination and that the clinical diagnosis is in dependent of whether or not arthrography is performed preoperatively

RESUME

Compte rendu d un matriel d observation examine pendant une periode de 3 ans et comprenant 166 malades avec lesions mensicales cliniques douteuses demandant une arthrographie Les trouvailles arthrographi ques ont ete verifiees a l operation ou par des examens complementaires chez les malades non operes Il est discute de l exactitude du diagnostic arthrographique afin de voir si le diagnostic clinique peut etre altere lorsqu on pratique l arthrographie les cas douteux ont été compares a deux series operatives de 2 ans Dans l une l arthrographie avait ete pratiquee avant l operation dans des cas ou les trouvailles cliniques

étaient douteuses alors que dans l'autre série il n'avait pas été fait d'arthrographie

Il est conclu que le manque d'exactitude de l'arthrographie est aussi grand que celui de l'examen clinique et que le diagnostic clinique n'a aucune dépendance du fait que l'atrhrographie a été pratiquée ou non avant l'opération

ZUSAMMENFASSUNG

Dies ist Bericht uber ein 3 jähriges Material das 166 Patienten mit klinisch zweifelhaften Meniskusschäden an denen eine Arthrographie vorgenommen wurde umfasst Die artherographischen Befunde wurden mit denen bei der Operation oder bei der Nachuntersuchung der nicht operierten Patienten verglichen Die Genauigkeit der artherographischen Diagnose wird erortert Um festzustellen ob die klinische Diagnose in zweifelhaften Fällen mittels Arthrographie verändert werden kann wurden zwei 2 jährige operative Gruppen miteinander verglichen In der einen wurde eine præoperative Arthrographie vorgenommen in Fällen wo die klinische Diagnose zweifelhaft war während in der anderen keine Arthrographie ausgefuhrt wurde Man kommt zur Schlussfolgerung dass die Ungenauigkeit der Arthrographie ebenso gross wie die klinische Untersuchung ist und dass die klinische Diagnose unabhängig davon ist ob eine Arthrographie vor der Operation ausgeführt oder nicht ausgefuhrt wurde

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OPERATIVE TREATMENT OF ANKLE FRACTURES

By

KAARLO A. SOLONEN & LEO LAUTTAMUS

Received 2[illegible] iv 67

The present study is a continuation of an investigation in which a series of ankle fractures from the period 1950–1963 were studied (*Solonen & Lauttamus* 1965) Our aim is now to assess the value of operative treatment

MATERIAL

During the period 1964–1965 all together 489 patients with ankle fracture were treated at our Clinic This figure does not include outpatients

The fractures are classified according to Lauge Hansen Palmer in Table 1

Sex

There were 236 males and 253 females

The different types of fracture were evenly distributed between both sexes with the exception of the SE group which comprised 141 females and 103 males

Age

The patients ages ranged from 11 to 86 years

The average age of the males was 36 that of the females 48

Nature of Accident

The accidents are classified according to type in Table 2

Slipping or stumbling cause the highest number (60 per cent) of SE fractures In traffic accidents, particularly when the patient had been hit by a motor vehicle or had fallen from his motor-cycle I and S fractures were the commonest

Treatment

Treatment was operative in 3[illegible]0 cases (72 per cent) and conservative in 139 ([illegible]8 per cent)

At follow up we found that 75 (54 per cent) of the patients treated conservatively should have been treated surgically and that 13 patients (4 per cent) who had been operated on should have received conservative treatment

Table 1 Classification of injuries

Type	No of patients	%
S I	4	9
S II	41	
SE I	2	50
SE II	14	
SE III	11	
SE IV	217	
P I	22	17
P II	3	
P III	60	
PE III	18	18
PE IV	68	
Irregular	29	6
Total	489	100

Table 2 Nature of the accident in various groups

Group	Slipping or stumbling %	Traffic accident %	Fall or jump %	Miscellaneous %
S	20	45	16	19
SE	96	2	–	2
P	65	22	5	8
PE	80	5	12	3
Irregular	38	10	28	24

Time of Operation

Operation was generally carried out on the day of the injury or the following day For various reasons (such as late presentation for treatment skin injury attempted conservative treatment) the operation was not done until as much as 2 weeks after the accident

(The majority of the surgical cases were treated without preceding conservative treatment)

Operation

The technique varied owing to the large number of surgeons In the absence of contra indications a tourniquet was used After reduction the fracture was fixed

with screws in 3?8 cases but in fracture of the fibula medullary nailing (Rush) was used in 1? cases and in some cases chromic catgut or steel wire cerclage as the only or supplementary fixation The deltoid ligament was sutured in 35 cases

After treatment

After the operation plaster was applied up to a level below the knee The plaster was removed after an average period of 8 weeks The patients left hospital four to three weeks after the operation. In cases where weight bearing was considered possible the plaster was replaced by a walking cast after 4 to 6 weeks In other cases, when consolidation was considered reliable The transsyndesmotic screw was removed at the latest after ? to 3 weeks unprotected weight bearin

RESULTS

Our assessment is based on the situation when the patient returned to work and on radiographic examination it being too early to say anything definite about the late results



Figure 1 In S II fracture surgical repair is sometimes the best treatment



Figure 2 A posterior marginal fracture of the tibia can often not be treated conservatively Reliable fixation may require two screws

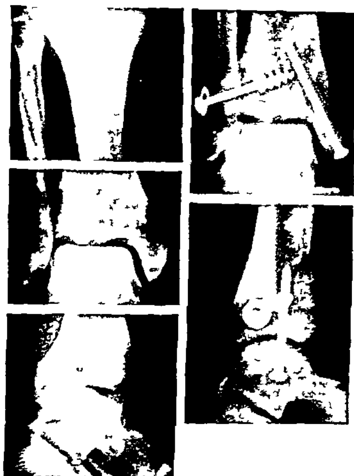


Figure 3 An ankle with a severe PE IV injury may appear intact in an antero posterior radiogram The safest procedure is to fix both the syndesmosis and the malleolus fracture and to suture torn ligaments (Lag screw is not advisable)

Grading of the Results

The result was accepted as radiographically good only when there was complete anatomical restoration Thus no cases with dislocation or angulation of the medial or lateral malleolus were placed in this category A posterior marginal fragment comprising one quarter or more of the width of the tibia also had to be replaced exactly and no dislocation of the talus was allowed Fair No medial or lateral dislocation of the malleolus and no angulation were accepted Dorsal dislocation of the lateral malleolus should not exceed 2 mm and the large posterior tri

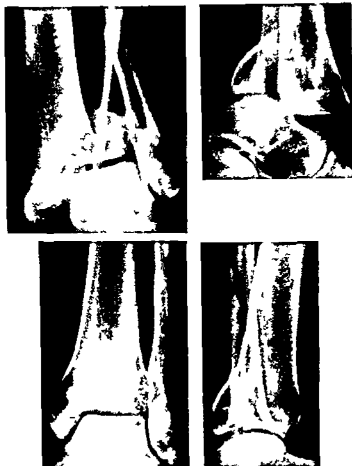


Figure 4 Persistent displacement of the posterior marginal fragment is an unsatisfactory result of conservative treatment of a PE IV injury

angular fragment should not be elevated by more than 2 mm No dislocation of the talus was allowed

Results not filling these requirements were recorded as unsatisfactory Otherwise we followed our earlier grading (1965)

The results in the series as a whole were the same as in our series of 1961–1963 acceptable results (good and fair) 88 per cent unsatisfactory 12 per cent

However if the operatively treated cases (350 cases) are considered separately we obtain following results acceptable in 95 per cent (good 76 per cent fair 19 per cent) and unsatisfactory 5 per cent In conser

vatively treated cases the corresponding figures were acceptable in 80 per cent (good 40 fair 40 per cent) and unsatisfactory in 20 per cent.

The results of operative treatment in the individual groups are given in Table 3.

The results of conservative and operative treatment cannot be compared since in our opinion the method of treatment is decided by the type of the fracture.

Of the 13 cases operated upon unnecessarily the result was good in 9 and fair in 3 and unsatisfactory in 1.

Table 3 Results in different groups of injury

Group	Total number of operated patients	Results (per cent of total number)		
		Good	Fair	Unsatisfactory
S I	2	100	–	–
S II	26	84	8	8
SE II	9	89	11	–
SE III	8	100	–	–
SE IV	161	70	27	3
P I	18	100	–	–
P II	2	100	–	–
P III	41	78	17	5
PE III	12	75	25	–
PE IV	54	74	13	13
Total	350	76	19	5

Complications

There were no infections of significance. Mild brief infection occurred in the operative wound in 3 cases.

The operation did not delay ossification or cause non union. In the conservatively treated cases there were several cases of non union.

No deaths occurred nor was thrombosis or embolism diagnosed.

Return to Work

The average period during which the patients were incapacitated for work was 4.3 months in conservatively treated cases and 4.5 months in operatively treated cases.

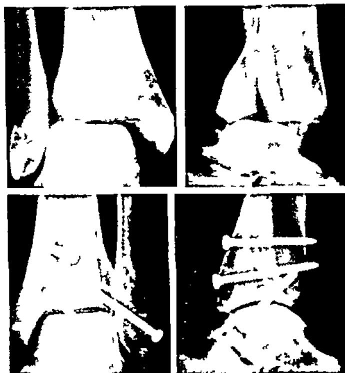


Figure 5 A SE IV injury was treated operatively the fractures were fixed with screws the deltoid ligament and the anterior tibio fibular ligament were sutured (Unnecessary fixation of the lateral malleolus with a transsyndesmotic screw)



Figure 6 In the treatment of a SE IV injury the result shown by an antero-posterior roentgenogram appeared to be good Later a special projection revealed troublesome dislocation of the lateral malleolus



Figure 7 Inadequate treatment The fragment of medial malleolus has not been reduced the talus is laterally dislocated the fragment of the lateral malleolus has been fixed in the wrong position by transsyndesmotic and wrongly directed screws The fragment of the medial malleolus ought to have been reduced and fixed the talus should have been reduced the anterior tibio fibular ligament should have been sutured and after reduction the fracture of the lateral malleolus should have been fixed only to the fibula with a screw or nail

DISCUSSION

Faults in Treatment

Reduction of the *lateral malleolus* was imperfect in 101 cases Faulty reduction of the lateral malleolus was the commonest fault in both the conservatively (30 per cent of the series) and the operatively (12 per cent of the series) treated cases The malleolar fragment remained dislocated proximally laterally posteriorly and in outward rotation A shortened fibula may provoke valgus deformity The site of the fracture must be exposed Fixation of the malleolus to the tibia at any rate without exact reduction cannot be regarded as adequate treatment

A *large posterior fragment* had remained elevated in 31 cases in 14 of the conservatively and 17 of the operatively treated cases In 10 of these cases the end result was poor in the rest fair Operative reduction is not as a rule difficult if the incision is correct but fixation with only one screw is often inadequate Even after good reduction of a large posterior fragment dorsal flexion of the foot remained limited In these cases the foot should perhaps be postoperatively immobilized in slight dorsal flexion

Unsatisfactory reduction or retention of the *medial malleolus* impaired the result in 12 conservatively and 3 operatively treated cases



Figure 8 The screw in the medial malleolus introduced at the wrong point and directed wrongly resulting in faulty positioning of the malleolus The fracture of the lateral malleolus is neither reduced nor fixed



Figure 9 The screw in the lateral malleolus is wrongly directed and pointlessly transsyndesmotic

Pseudarthrosis of the malleolus was seen in 7 conservatively treated cases This shows that these cases should have been treated surgically On the other hand a small avulsion fracture of the malleolus does not by itself require operation Neither is pseudarthrosis in



Figure 7 Inadequate treatment The fragment of medial malleolus has not been reduced the talus is laterally dislocated the fragment of the lateral malleolus has been fixed in the wrong position by transsyndesmotic and wrongly directed screws The fragment of the medial malleolus ought to have been reduced and fixed the talus should have been reduced the anterior tibio fibular ligament should have been sutured and after reduction the fracture of the lateral malleolus should have been fixed only to the fibula with a screw or nail

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Figure 11 Operative treatment of SE IV injury with reduction and fixation of the fracture of the medial malleolus with screws and the fibular malleolus by temporary cerclage the anterior tibio fibular ligament being sutured

such a case a source of inconvenience Such cases are not included in the above figure At operative treatment of the medial malleolus perio steal interposition was often seen

Faulty operative treatment of a *syndesmotic lesion* was apparent in 21 cases the screw having been left for too long or removed too early The former caused limited mobility and a *wooden feeling* (*Bonnin* 1950) or breaking of the screw After too early removal of the screw the syndesmosis spread in 3 cases in 1 case even after 9 weeks In 2 cases the syndesmosis had been too firmly tightened As a rule the syn desmosis screw had been left in place for 10 to 11 weeks Fixation of the lateral malleolar fragment with a transsyndesmotic screw in SE and P injuries caused unnecessary traumatization of the syndesmosis *Burwell & Charnley's* method (1965) is preferable but we doubt whether this is sufficient in PE fractures with complete rupture of the syndesmosis In these cases we consider fixation of the syndesmosis important Otherwise mono osseal fixation of fractures with suturation of ruptured ligaments is sufficient

Non diagnosis or faulty assessment of *ligamental lesions* are among the commonest errors Lauge Hansen's genetic system clearly shows the nature and extent of the injuries in question A ligamental lesion is sometimes as important as a fracture Non suturing of a ruptured deltoid ligament was in our opinion a fault in 28 cases (15 of which had been operatively treated) It is true that insufficiency of this liga

ment was observed in only 4 cases but healing of the ligament is quicker and more reliable after suturation than after cicatrization It is impossible for instance without operation to retract the ligament from between the malleolus and the talus where it is sometimes displaced and where it prevents reduction of the talus Further the posterior tibial tendon may be interposed between the ligament and its insertion If these possibilities did not exist one could certainly agree with *Bonnin s* (1965) opinion that the bulk of the ligament and its natural form maintain apposition of the torn ends and surgical repair is very seldom needed

Insufficiency of the lateral collateral ligaments was observed in 3 cases This injury is rarer in connexion with fractures than with sprain but it must be dealt with Lesion of the inferior tibio fibular ligament is very common as is clearly and correctly demonstrated by Lauge Hansen s classification It is evident that some of the numerous dislocations of the lateral malleolar fragment result from failure to suture this ligament Suturation should be done after reduction and fixation of the fracture of the lateral malleolus and it may easily be performed through the same incision

The *direction and point of entrance of the screw* were often faulty The site and direction of the screw are of decisive importance in securing the position of the fragment One cannot simply state that a trans syndesmotic screw from the fibula should be placed horizontally or obliquely The direction of the screw depends on the individual fracture It is important that the fracture should be carefully reduced under visual control before fixation otherwise a dislocation will almost always persist

A screw inserted too close to the cartilage seems to irritate and may even cause nutritional disturbance of the cartilage

Wrong type of screw A lag screw is ill suited for these fractures it is too thick and to tighten it requires so much force that the fragment often turns with the screw This error had been made in 6 cases

It is advisable to drill a wide hole for the screw particularly in the medial malleolus The proximal part of the screw should preferably be without threads The screw should reach to the opposite corticalis or near it

Unnecessary operations With the exception of PE fractures in which operative treatment especially of rupture of the syndesmosis is in our opinion a more reliable procedure than conservative treatment fractures without dislocation should not be repaired surgically However

whether operation is necessary or not should be decided separately each individual case and not simply according to type

Operative Technique

The choice of the operative approach has sometimes been fau Fracture of the medial malleolus or rupture of the deltoid l ment may well be repaired through a distally curving incision terior or posterior to the malleolus A lateral malleolar fract the anterior tibio-fibular ligament and the syndesmosis are expo through an antero lateral incision placed exactly over the syndesmo

A posterior marginal fracture is repaired through a postero lat incision

Procedure A posterior marginal fracture that requires surgical pair is treated first—with the patient prone—and then the lat malleolus In SE fractures the posterior marginal fracture and fibular fragment constitute an entity united by the ligaments wh facilitates reduction The posterior marginal fragment must often fixed with two screws for otherwise a primarily good apposition be lost in the plaster cast

Closed wound suction is recommended for a period of 1 to 2 d *Plaster cast* should be evenly padded and carefully moulded The must be split anteriorly

CONCLUSIONS

Since we know that the primary result is generally permanent *lonen* & *Laullamus*) and that accurate reduction is the best prop laxis against arthrosis (*Jergesen* 1959 *Klossner* 1962) rigorous mands must be made on the primary treatment of ankle injuries

A prerequisite for good results is exact diagnosis which is poss only if the entire mechanism of the injury is fully understood Lauge Hansen genetic classification is the most satisfactory of those know and provides a key to the understanding of the damage a whole It must be remembered that the lesion in question is not a f ture of a bone but an injury to a complex weight bearing joint

It is often impossible to achieve a sufficiently satisfactory result conservative methods particularly in the treatment of lesions of l ments and of the syndesmosis but also in fractures of various types therefore often consider operative treatment indicated particularl SE II-IV and PE II-IV injuries But the indications must be evalua separately in each case All significant components of the injury m

be repaired After exact reduction firm fixation must be achieved Together with faulty treatment of ligamental injuries unsatisfactory reduction of fracture of the lateral malleolus is one of the commonest faults The majority of the errors we have detected can be eliminated We have not observed any disadvantages of operation when it has been indicated and performed with the necessary technical skill

Convalescence is not significantly longer after operative than after conservative treatment

SUMMARY

This paper presents 489 patients with ankle injuries treated during a period of two years 350 patients were treated operatively Surgical repair led usually to acceptable results (95 per cent) The result would have been better if the whole extent of the injury had been understood in all cases Technical skill is of high importance in the treatment of these severe injuries

It is not a question of treatment of a bone fracture but of an extensive joint injury *Syndesmotic and ligamental lesions should be repaired* Unsatisfactory treatment of these and of fracture of the lateral malleolus are the commonest causes of poor results

The manifold components of the injury *are difficult to repair conservatively* Operation is often indicated and no significant disadvantages of surgical repair were observed in the present series However each case must be evaluated separately and classification of the type of injury alone is not a sufficient basis for assessing indications for operation

RESUME

Cette etude presente 489 malades avec lesions de la cheville traites durant *une periode de deux ans 350 malades ont ete operes* L intervention chirurgicale a abouti a une proportion elevée de resultats relativement satisfaisants (95 pour cent) Les resultats auraient pu etre encore meilleurs si l on avait compris *dans tous les cas l etendue de la lesion* L habileté technique est de la plus haute importance dans le traitement de ces graves lesions

Il n est pas question du traitement d une fracture osseuse mais *d une* lesion articulaire etendue Les lesions syndesmotiques ou ligamenteuses doivent etre reparees Un traitement peu satisfaisant de celles ci et de la fracture de la malleole laterale sont les causes les plus courantes de mauvais resultats

Les multiples elements de la lesion rendent difficile un traitement

conservateur L opération est souvent indiquée et l on n a pas observé dans la présente série de désavantages provenant de l intervention chirurgicale Quoi qu il en soit il convient d apprécier chaque cas en particulier et la classification du type de lésion n est pas à elle seule suffisante comme base d indication opératoire

ZUSAMMENFASSUNG

Diese Arbeit stellt 489 Patienten mit Knöchelschäden während eines Zeitraumes von zwei Jahren vor 350 Patienten wurden operativ behandelt

Chirurgische Wiederherstellung führte in einer grossen Anzahl zu guten Ergebnissen (95 Prozent) Die Ergebnisse wurden noch besser gewesen sein wenn die Ausdehnung der Beschädigung in allen Fällen ganz verstanden worden wäre Technische Fertigkeit ist bei der Behandlung dieser schweren Schäden sehr wichtig

Es dreht sich nicht um die Behandlung eines Knochenbruches sondern um einen ausgedehnten Gelenkschaden Syndesmose und Bandschäden sollten wiederhergestellt werden Ungenügende Behandlung derselben und des Bruches des lateralen Knochels sind die gewohnlichsten Ursachen von schlechten Ergebnissen

Die vielfaltigen Komponenten der Beschädigung sind schwierig auf konservativem Wege zu behandeln Operation ist häufig angezeigt und keinerlei Nachteile von Bedeutung wegen des chirurgischen Eingriffes wurde in dem vorliegenden Materiale beobachtet Jeder Fall muss jedoch separat beurteilt werden und Klassifizierung der Type der Verletzung allein ist keine genügende Grundlage zur Bestimmung der operativen Anzeige

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METABOLIC AND ORTHOPEDIC TREATMENT OF A CASE OF ADULT NONFAMILIAR HYPOPHOSPHATEMIA WITH SEVERE OSTEOMALACIA

By

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Received 21 x 67

The first adult case of the Fanconi syndrome was described by *Stowers & Dent in 1947* (1) The syndrome consists of osteomalacia with hypophosphatemia, glucosuria aminoaciduria, and frequently acidosis There is sometimes a defect in the water retaining ability of the kidney as well *Wallis & Engle* (2) who reported on eighteen adult cases of the syndrome claimed that multiple familial occurrences are rare in adults whereas a hereditary tendency is common in children with the syndrome

A condition which shares many features with the Fanconi syndrome is renal tubular osteomalacia in which the serum calcium is usually normal the serum phosphorus always low and the alkaline phosphatases increased and in connection with which there is no aminoaciduria and usually no glucosuria Familial instances of this disease are common but isolated cases also occur High doses of vitamin D can improve the patient s osteomalacia The first case of vitamin D resistant osteomalacia is said to have been presented by *Albright et al* in 1937 (3) but the case described by *Milkman* in 1934 (4) which had osteomalacia hypophosphatemia and glucosuria probably belongs to the group of vitamin D resistant osteomalacia with hypophosphatemia Most investigators have found a low tubular reabsorption of phosphate in these cases In children the disorder causes rickets resistant to treatment with vitamin D in doses sufficient to cure nutritional rickets and is therefore often called vitamin D resistant rickets In adults the hypophosphatemia causes osteomalacia and these adult disorders have

been called phosphate diabetes essential hypophosphatemia idiopathic osteomalacia Milkman s syndrome etc

There seems to be some controversy in the literature with regard to the classification of the various clinical conditions characterized by osteomalacia (or rickets in children) and hypophosphatemia due to decreased tubular reabsorption of phosphate Many textbooks describe the Fanconi syndrome and hypophosphatemic osteomalacia in different chapters (5 6) What seems ultimately to differentiate the Fanconi syndrome from hypophosphatemic osteomalacia is the aminoaciduria which according to most authors is an integral part of the Fanconi syndrome

Dent (7) has suggested a classification of clinical conditions with rickets and osteomalacia from renal tubule defects in six different types According to his classification type 1 denotes osteomalacia in which there is only one human tubular reabsorption defect namely that of phosphate In type 2 renal glucosuria occurs as well The different types of the Fanconi syndrome and hypophosphatemic osteomalacia with renal tubular acidosis are classified as types 3–6 In our opinion this classification is very useful from diagnostic therapeutic and prognostic viewpoints

The main problem with vitamin D treatment in hypophosphatemic osteomalacia lies in the fact that high doses are required in most cases and are accompanied by the constant risk of intoxication with the vitamin It was consequently of great interest when *Fraser* (8) reported in 1957 that intravenous phosphate had a beneficial effect in vitamin D refractory rickets in children In 1958 and 1961 *Frame et al* (9 10) showed that oral phosphate supplement was effective in hypophosphatemic osteomalacia and it was further shown in 1963 by *Wilson & Yendt* (11) that two cases with the adult Fanconi syndrome were improved with oral phosphate treatment alone without vitamin D supplement The role of phosphate therapy in hypophosphatemic rickets and osteomalacia has also been stressed by *Rose* (12) Oral phosphate supplementation is also appealing from the point of view that phosphate administration seems to protect against hypercalcemia of all etiologies (13) and therefore also against the hypercalcemia due to vitamin D intoxication

In the present paper we will report on a case of very severe hypophosphatemic osteomalacia in a man of 27 and the gratifying effect of orthopedic correction in combination with long term treatment with high doses of vitamin D and sodium monophosphate

METHODS

Phosphorus in serum urine feces and food specimens was determined by the method of *Fiske SubbaRow* (14) *Calcium* in the same media was estimated with flame photometry *Alkaline phosphatase* was determined by the method of *Bessey Lowry & Brock* (15) as modifed by *Jacobsson* (16) Quantitative analysis of the amino acids in the urine was performed by means of an automatic amino acid analysor (17) as by *Spackman Moore & Stein* (18) Trace element determinations were performed with a recently developed ion exchange technique with subsequent γ spectrometry (19) after neutron activation

For long periods the patient underwent studies of calcium and phosphorus balance For shorter periods balance studies were also undertaken with respect to 25 different trace elements During the balance study the patient was kept on a constant daily menu that he had chosen himself Feces and urine was collected during five day periods Calcium and phosphorus (and during certain periods trace elements) were determined on aliquots of urine and homogenates of feces The intake of calcium and phosphorus and trace elements was determined by analysis of homogenates of duplicates of each day s meals All drugs given were added to the model diet before homogenization The balance data obtained were charted as by *Reifenstein et al* (20)

CASE REPORT

On admission the patient was 26 years old Up to early 1965 he had worked as a mechanic The patient has two brothers and one sister all healthy The father has six healthy brothers and sisters the mother has two healthy brothers and one brother who died from an unknown heart disease at the age of 25

The patient had developed normally as a child and there is no history of rickets

The symptoms started at the age of 16 During 1956–59 there were slowly increasing skeletal pains in the ribs lower back the left knee and the right shoulder but the patient was still able to participate in football and other vigorous activities In 1959 at the age of 19 he called the local hospital and during that year several roentgenograms were taken which revealed fourteen Milkman fractures some in a state of healing others showing no callus In late 1959 the patient developed pains in the hip joints X rays showed fractures in the pelvis ring and in both tibiae and fibulae

In 1959 hypophosphatemia and renal glucosuria were detected and the disorder was considered thereafter to be a Fanconi syndrome The same year treatment with approximately 50 000 I U vitamin D daily was started and was maintained during the four years preceding the development in 1963 of gastric ulcer which led to a Billroth II gastrectomy Thenceforth the vitamin D therapy was omitted for unclear reasons During the period between 1959 to 1963 there were no gross changes in body stature His body height decreased only slightly during this period from 176 to 173 cm There were constant skeletal pains however which were especially severe in the hip joint X ray revealed bilateral Milkman fractures of collum femoris

During 1964 the patient s symptoms did not progress despite the lack of vitamin D therapy



Figure 1 The patient on admission to the metabolic ward

In early 1965 however the symptoms progressed rapidl and within two or three months the patient had developed a severe thoracic kyphosis and the sternum was fractured at a 90 angle Body height decreased from 1/3 to 159 5 cm a dramatic change in three months (Figure 1) Severe pains as well as muscular fatigue in the legs and hip joints bound him to the wheelchair A compound tablet containing 4 800 I U vitamin D and 600 mg calcium daily was then prescribed but the patient had lost all confidence in doctors and took the tablets only sporadically He was severely depressed

The patient was admitted to the metabolic ward Serafimer hospital in January 1966 with the diagnosis of Fanconi syndrome He was mentally depressed and severely crippled b marke l thoracic kyphosis pidgeon chest generalized muscular weakness and constant skeletal pain The pains were alleviated by lying down He coul l not walk unaided and had for several months required analgesics con stantl

X ra showed 36 fractures of the Milkman type of variable age as illustrated in Figures 2 and 3 Serum ph sphorus was extremely low whereas serum calcium was n rmal There was al o renal glucosuria l ut no pathological aminoaciduri As a re ult of these findings it was suggeste l that this was a case of h popho phatemic osteomalacia with glucosuria thus being a hypopho phatemic osteo malacia f type II I the Dent cl s ification (i) rather than a Fanconi ndr me More letaile l information on roentgenographic an l lal or tory fin lings is given un ler sej arate headings later in the text

After routine examination the patient was sul jecte l to m taboli l alance stu lies during ?? consecutive 5-day bal nce perio l i e 110 la During the first two control peri ls he was given tl e same d e f itamin D 4 00 I U as pre

Figure 2 The roentgenogram to the left illustrates the cod fish vertebra typical for advanced osteomalacia Note the collapse of T6 resulting in a gibbus of approximately 90° The right figure shows the fracture of the sternum causing pigeon chest



Figure 3 Roentgenograms showing Milkman fractures in the scapulae and in the tibia and fibula before and after metabolic treatment of the osteomalacia After treatment the fractures are healed

scribed before admission During the following periods increasing amounts of vitamin D calcium and phosphate were given After five months the medication consisted of 545 000 units of vitamin D_2 3 g calcium and 15 g sodium monophosphate

The patient first noticed a decrease in pain after about four weeks of effective treatment After about two and a half months the muscular weakness and pain

had diminished and the patient was able to walk without walking sticks although he had marked waddling gait. After a few minutes of walking pains would develop in the hips and force him to rest In late April he was able to be up and about for several hours during the day and experienced pains only in the afternoon After a little more than five months of a combined regimen of phosphate calcium and vitamin D the patient was discharged from the metabolic ward for a planned three months "summer vacation He was fully mobilized with no pain and scarcely any waddling gait The patient was optimistic and his depression had vanished. The orthopedic treatment had been quite successful (see under orthopedic treatment) the patient s body height having been increased from 159 5 to 165 cm

During the summer of 1966 the patient s subjective well being continued and the serum calcium and phosphorus values were normal In the middle of August however there was a bout of hypercalcemia and the patient was therefore im mediately admitted to the metabolic ward The patient was in excellent condition physically (he was now able to run and to jump from 50 cm heights without pains) and his muscular strength was normal The vitamin D_2 was omitted for about one month in order to restore normal calcium values The patient again underwent metabolic balance studies for two and a half months and was dis charged in late November Some adjustment of the medication (see under laboratory findings) was made subsequently and the patient is currently (August 1967) re ceiving 100 000 units of vitamin D and 15 g sodium monophosphate daily He is fully rehabilitated and works as an electronic technician

FAMILY STUDIES

No other case of rickets osteomalacia or other metabolic bone disease is known in the patient s family Blood and urine specimens from both parents and all siblings (? males and 1 female) were investigated for the presence of glycosuria and amino-aciduria and determinations were made of serum concentrations of calcium phos phorus creatinine and alkaline phosphatase All these tests were found to be normal

EFFECT OF THERAPY ON CALCIUM AND PHOSPHORUS METABOLISM

A few days after admission in January 1966 the patient was put on a balance diet with an intake of exactly 1000 mg calcium and 1100 mg phosphorus The vitamin D intake was 0 300 I U imitating the medica tion he had taken at home Only two 5 day control periods were studied due to the patient s poor condition which required treatment Both calcium and phosphorus balances were negative (see Figure 4) ini tially the calcium loss being 120 to 160 mg per day The urinary cal cium did not exceed 120 mg per day The phosphorus balance was close to equilibrium and the urinary phosphorus approximately 700 mg per day a rather normal value

During the following three balance periods the vitamin D dose was

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The patient first noticed a decrease in pain after about four weeks of effective treatment After about two and a half months the muscular weakness and pain

ance became strongly positive and during one of the two 5 day periods on this regime the calcium balance was positive.

During the following six balance periods the treatment was unchanged except for an increase of the calcium intake from 1000 to 3300 mg per day (Calcium Sandoz effervescent tablets). Thereafter the patient was in positive phosphorus and calcium balance. The urinary calcium never exceeded 200 mg per day on this medication but the urinary phosphorus was very high 2500 to 2900 mg.

The serum phosphorus was low despite of the positive calcium and phosphorus balances. The dose of vitamin D was therefore increased from 120 000 to 370 000 units in balance periods 14 and 15 (April) while the phosphate and calcium intakes were unchanged. This normalized the serum phosphorus. The patient was then able to walk without support during short periods and the skeletal pains had decreased. The muscular weakness had improved.

At the end of the third month (balance period 16) the phosphate dose was increased to 15 g per day (corresponding to 3 g phosphorus) and with that dose serum phosphorus has been constantly normal. One month later (balance period 2 beginning of May) the dose of vitamin D_2 was further increased to 545 000 units a day. By now the patient was able to move around without crutches or support although he had a typical waddling gait. After 15 minutes or so of walking the patient developed pains in the hip joints and had to rest. At the end of May however muscular strength was nearly normal (as was the electromyogram) and the patient was completely mobilized. There was still a slight waddling gait. The patient left the hospital in the beginning of June after almost six months in hospital. The patient was now in strongly positive calcium and phosphorus balance retaining about 1500 mg of calcium and about 1000 mg of phosphorus. The serum calcium and phosphorus were normal and the extremely large dose of D (545 000 units) had not produced hypercalcuria.

During two and a half months at home the rather heavy medication was kept constant (545 000 units of vitamin D_2 3000 mg phosphorus and 2280 mg calcium as tablets). Check ups of serum calcium phosphorus and alkaline phosphatase and creatinine were made at four week intervals and the urinary calcium was also determined. Physically the patient improved steadily. In the beginning of August however a high serum calcium value (5.7 mEq/l) was seen for the first time and the patient was therefore readmitted to the hospital.

On admission in August 1966 the serum calcium was high 5.7–6.0

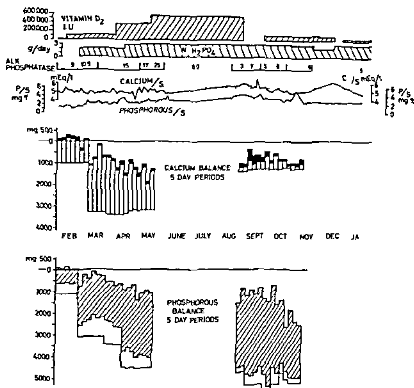


Figure 4 Balance studies of calcium and phosphorus in the patient Intake is plotted downwards from the base line output is plotted from the bottom of the intake upwards The solid and the open parts of the columns represent urinary and fecal excretion respectively In the case of a positive balance all parts of the columns are below the base line but if the balance is negative a part of the columns is above the baseline —The figure also shows the alterations in treatment with vitamin D_2 oral phosphate and calcium as well as variations in the serum calcium phosphorus and alkaline phosphatase

increased to 120 000 units That dose of vitamin D obviously failed to change the phosphorus balance and the calcium balance did not become positive The patient reported no subjective improvement

During balance periods 6 and 7 sodium monophosphate 10 g per day (corresponding to about 2 g phosphorus) was given orally The salt was given three times a day in fruit juice and the patient found the taste of this mixture to be acceptable (he has taken it for more than a year now without serious objections) The pH of the divided salt doses in distilled water was 4 8 On the combination of 10 g sodium monophosphate and 120 000 units of vitamin D the phosphorus bal

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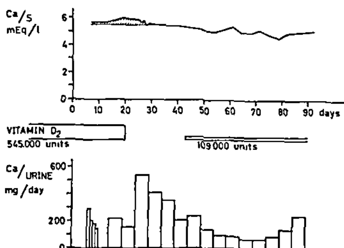


Figure 5 Serum and urinary calcium during a period of slight vitamin D_2 intoxication

mEq/l and the urinary calcium was 294 mg also a high value The patient's calcium and phosphorus balances were restudied for fifteen 5 day periods Despite the omission of both vitamin D and calcium the urinary calcium was high for three balance periods (Figure 5) The serum calcium became normal 1–2 weeks after omission of the vitamin (Figure 4) The calcium tablets and all vitamins were omitted for about one month and during this period calcium fell to 5 2–5 5 mEq/l After four weeks without vitamin D a dose of 109 000 units was instituted For the ten following balance periods the calcium and phosphorus metabolism was acceptable as judged from the studies of balances and blood chemistry and the patient was discharged for out patient control

In December 1966 the phosphate intake was lowered to 10 g/day due to the possible interference by oral phosphate with iron absorption (see below) This was followed by a new bout of hypercalcemia (Figure 4) After 10 days omission of D and reinstitution of 15 g phosphate/ day a lower dose of 45 000 units of D was begun

EFFECT OF TREATMENT ON TRACE ELEMENT BALANCES

The balances for the following trace elements were determined before (balance period 1) and during (period 22) treatment As Ba Cd Co Cr Cs Cu Fe Hg Rb Sb Se and Zn Among the trace elements with known biological function (Figure 6) Co showed a negative bal

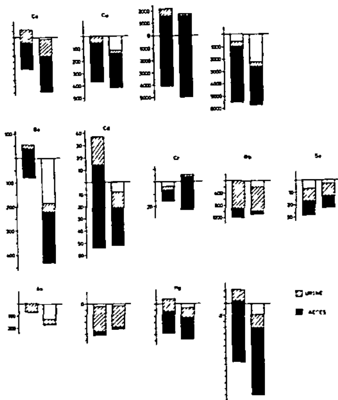


Figure 6 Trace element balances before and during treatment with oral phosphate and vitamin D_2 (for key see legend to Figure 4)

ance before and a positive balance during treatment The balances of Cu and Zn were somewhat more positive after treatment than before On the other hand the Fe balance was negative before as well as after treatment

Among the balances of trace elements with suspected biological function the Cr Rb and Se balances were not changed in any definite way by treatment The Ba balance was very similar to the Ca balance (Figures 4 and 6) The Cd balance like the Ba balance was negative before and positive after treatment

Some trace elements without known biological function were also determined Among these elements the balances of As Hg and Sb became positive during treatment while the Cs balance was unchanged by treatment

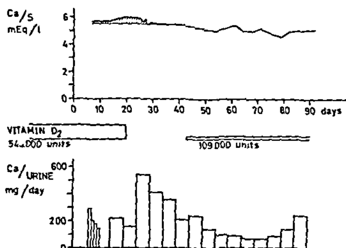


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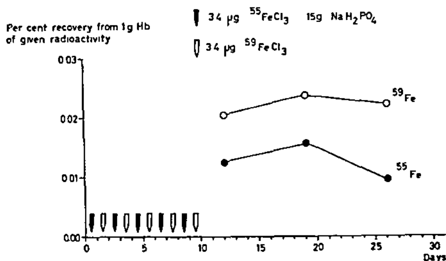


Figure 7 Double isotope study with regard to the effect of oral phosphate therapy on iron absorption The Fe isotope given together with phosphate was incorporated more slowly into hemoglobin than the other isotope which was given without phosphate

furniture Although the muscle weakness was generalized it was obvious that the muscles of the shoulder and the pelvis were most severely affected There were however no contractures

A definite improvement in muscular strength was experienced by the patient after he had been in positive calcium and phosphorus balances for about one month After 6–9 months of treatment the muscular strength could be considered as normal

Electromyography was performed at three occasions before treatment was started and after six and nine months of treatment In the first recording typical signs of myopathy were found In the second there was an obvious improvement but still a slight overrepresentation of "thin action potentials The third recording after 9 months of treatment was considered to be normal

RENAL FUNCTION

Before treatment was started serum creatinine was 0.75 mg per 100 ml and the glomerular filtration rate 140 ml/min (endogenous creatinine clearance) During the first 4 months of hospital treatment the serum creatinine was checked every week and was lower in all instances than 0.9 mg per cent At the peak of hypercalcemia in August the

same year however (Figure 4) the serum creatinine was 1 2 mg per 100 ml and the filtration rate 92 ml/min In April of 1967 renal function tests were as follows serum creatinine 0 8 mg per cent endogenous creatinine clearance 88 ml/min inulin clearance 80 ml/min

ALKALINE PHOSPHATES

On admission the alkaline phosphatase was 19 Bessey Lowry units (upper limit of normal = 2 5 units) It stayed only moderately elevated (6–10 units) until the calcium and phosphorus balances had been positive for about three weeks at which time it rose to 16 5 units but fell again to a level of around 10 units After the dose of 545 000 units of vitamin D was instituted in May the alkaline phosphatase reached its highest value of 25 units and remained high around 20 units for two months When the hypercalcemia occurred in late August of 1966 the alkaline phosphatase had dropped to 6 units Since then the value has been only moderately increased 5 to 10 units

ROENTGENOGRAPHIC FINDINGS

On admittance to the metabolic ward in January 1966 35 Milkman fractures were present in the skeleton in most sites where such fractures have been described in osteomalacia (22) The collum femoris showed varus position bilaterally The sternum was fractured at an angle of 90 There was a pronounced thoracic deformity with marked gibbus of 90 pidgeon chest and cod fish vertebrae There was also general and severe demineralization of the bone

The first roentgenographic evidence of osteomalacia such as patchy rarification of bones and Milkman fractures were observed in 1959 after a six month history of low back pain The roentgenological findings are summarized in Table 1

After five months of treatment with vitamin D *calcium* and phosphate there was generally increased callus formation in the fractures and after seven months all of the Milkman fractures had healed completely The low mineralization of the skeleton was still rather evident at this time however

MICRORADIOGRAPHY OF THE BONE TISSUE

Biopsy of the bone was taken twice before effective therapy was started in January 1966 and after about half a year of treatment in *October*

Table 1

1959 Body height 176 cm	*Febr* Fractures of transverse processes of L. L_3 and L_4 with moderate callus formation Fracture of the right 9th rib Rarefications in the 9th 10th and 11th ribs on right side Normal X ray of the pelvis hip joints and upper parts of femors *Nov* Additional destruction in the right 8th rib and the 8th and 9th ribs on the left side *Dec* Generalized demineralization of the skeleton "Old fractures bilaterally in the upper parts of the tibiae and fi bulae and in the fifth right metatarsal all of them showing callus formation
1960 Body height 175 cm	*March* Fracture without dislocation in the sacrum at the S_4 level. Now also fractures in the right superior and in ferior rami of the pelvis no dislocation
1963 Body height 173 cm	*Febr March* Demineralization of the skeleton more pro nounced than in March 1960 Compression of the thoracic vertebrae which now have a wedge like appearance The fractures in the pelvic ring are healed relative to March 1960 Fracture of the right femoral neck with slight varus dis location visible callus The old fractures in the tibiae and fibulae are still visible but largely healed. *May* Additional fracture of the right 6th rib
1965 Body height 163 cm	*Jan* Marked deformity of the thorax with pidgeon chest The left lateral portion of the rib cage is pressed medially The thoracic kyphosis has increased to almost 90 and there is a fracture of the sternum with an angulation of 90 The fracture of the right femoral neck is still visible as in 1963 but the varus dislocation is more pronounced There is now an almost identical type of fracture in the left femoral neck with a similar dislocation Fracture with callus of the right tibia 10 cm below the knee joint. The "old" fractures in the tibiae and fibulae from 1959 are still visible
1966 Body height 159 5 cm	*Febr* The whole skeleton is reexamined, and compared with Jan 1965 None of the fractures are healed. Recent multiple fractures in both scapulae Extensive demineralization of the whole skeleton
Body height 165 cm	*Sept* Continued low mineralization of the skeleton All frac tures are healed

1966 The specimens were taken from the lateral part of the iliac crest Thus the material studied was composed mainly of cancellous bone At the first biopsy the bone was very soft and elastic and was felt by the palpating finger as a piece of rubber The bone specimen could be

The possible gains from such an operation were considered small relative to the risk of impairment of respiratory function

The loss of body height could not be attributed to the thoracic deformity alone The fractures of the femoral necks resulting in a marked varus position in both hip joints caused shortening of the legs which could be estimated as 3 to 5 cm The varus deformity also constitutes a risk of future osteoarthritis of the hip joints Although this possibility could be considered an indication for corrective osteotomy of the femoral necks the procedure has not been done thus far Furthermore it was considered unwise to immobilize the patient for another prolonged period by such operations and thus again delay his rehabilitation It is possible however that orthopedic surgery will have to be performed at some time in the future if signs of arthrosis should appear in the hip joints

DISCUSSION

The characteristic features of the present case osteomalacia hypophosphatemia renal glucosuria in the absence of aminociduria and other tubular reabsorption defects fit well with the diagnosis of hypophosphatemic osteomalacia of Type II according to *Dent* s (7) classification with the important exception of the absence of a positive family history This particular disturbancy in renal tubular reabsorption must be extremely rare A survey of the pertinent literature has thus far revealed only six cases (4 7 12) comparable with the actual case In at least one of these cases no family history of metabolic bone disease was found Furthermore the type II tubular defect has occurred only in adults in contrast with the more common type I defect which obviously is far more common in children than in adults

The present case was complicated by a bleeding ulcer that necessitated gastric resection four years after the onset of symptoms of metabolic bone disease It is quite clear from the hospital records that the disease progressed rapidly after the gastric resection Two main factors seem to have contributed to this namely the lowering of the vitamin D_2 dose (for unknown reasons) from 50 000 to 5 000 units/day and the patient s dislike for dairy products which seems to have decreased his postoperative calcium intake to about 500 mg/day The gastrectomy did not seem to cause any significant malabsorption since the daily fecal fat excretion was found to be within normal limits

Compared to most reported cases of osteomalacia the generalized skeletal destruction observed in this case including a very rapid thor

acic deformation in the course of three months was remarkable Never theless the results of combined therapy with vitamin D_2 oral phosphate and calcium and orthopedic treatment was very gratifying and resulted in a total rehabilitation of the patient in less than one year

Most cases of hypophosphatemic osteomalacia have until now been successfully treated with large doses of vitamin D and frequently with calcium supplements In many cases this can bring about not only healing of fractures but also normalization of serum phosphorus (23 24) In this case 109 000 units of D did not normalize the serum phosphorus In view of the risks of vitamin D intoxication by higher doses as well as the protective effect of oral phosphate against hypercalcemia of all etiologies (13) it was decided to give oral phosphate in large amounts Further support for the use of phosphate therapy was obtained from the papers by *Frame et al* (9 10) and *Rose* (12)

The course of the combined D_2 and phosphate treatment was fairly uncomplicated in spite of the fact that more than 500 000 units of vitamin D_2 were given for several months Exceptions were two bouts of moderate hypercalcemia one after 7 months of treatment with very large doses of vitamin D (Aug Figure 4) and the second during the administration of a moderate vitamin dose in connection with an attempt to lower the phosphate dose (Dec Figure 4) The second episode of hypercalcemia offers some support for the abovementioned hypothesis that phosphate is of value in minimizing the risk of vitamin D induced hypercalcemia The question can be raised of whether in this case phosphate treatment alone could have produced the same good result healing of fractures and rehabilitation of the patient without the risk of vitamin D intoxication In fact two cases of the adult Fanconi syndrome are described where this has been tried evidently with good results (11) This type of therapy has been reported to be of little value in children with vitamin D resistant rickets however (25) The mentioned therapy was not systematically investigated in the present study

In spite of the fact that only two short periods of moderate hypercalcemia occurred during the treatment a slight impairment of glomerular filtration was induced by the therapy A plausible explanation for this undesirable effect is the well known vitamin D intoxication It cannot be ruled out however that the phosphate treatment *per se* carries the risk of inducing renal injury Some authors (5) have in fact reported unfavourable results with phosphate administration in renal tubular osteomalacia and they claim that it may cause renal in

D_2 phosphate and calcium he was completely rehabilitated By means of orthopedic extension treatment performed during the osteomalacic state some correction of the thoracic deformity was obtained which included a gain in body height of 5 5 cm The balances for calcium phosphorus and a number of trace elements were studied before and during treatment and are discussed The experience from this case supports the view that oral phosphate has a place in the treatment of hypophosphatemic osteomalacia

RESUME

Il est décrit un cas tres grave d osteomalacie hypophosphatemique non hereditaire avec glucosurie renale compliquée de résection gastrique chez un jeune homme de 27 ans Les premiers symptomes se sont mani festes a l age de 18 ans A 26 ans le malade était gravement invalide apres une perte de hauteur du corps de 16 5 cm le développement d une déformite thoracique et une myopathie proximale marquée Apres un an de traitement avec de fortes de vitamines D de phosphate et de calcium il etait entierement remis Au moyen d un traitement par extension orthopedique pratiquee durant l etat ostéomalacique une certaine correction de la deformite thoracique a ete obtenue avec une recuperation de 5 5 cm de la hauteur du corps Les metabolismes du *calcium du phosphore* et d un *nombre d autres elements* ont été étu dies avant et pendant le traitement et sont discutes L experience ac quise de ce cas soutient le point de vue que le phosphate oral a une place dans le traitement de l ostéomalacie hypophosphatemique

ZUSAMMENFASSUNG

Ein Fall von schwerer hypophosphstamischer nichterblicher Osteo malazie mit einer renalen Glykosurie kompliziert mit Ventrikelresek tion bei einem 27 jahrigen Mann wird beschrieben Die ersten Symp tome erschienen im Alter von 18 Jahren Mit 26 Jahren war der Patient nach dem Verlust von 16 5 cm an Korperhohe der Entwicklung einer thorakalen Deformitet und einer ausgesprochenen proximalen Myo pathie schwer *invalidisiert* Nach einer *einjahrigen* Behandlung mit hohen Dosen von Vitamin D Phosphat und Calcium war er vollstandig wiederhergestellt Mittels orthopedischer Streckung die wahrend des osteomalazischen Zustandes ausgefuhrt wurde konnte eine gewisse Korrektur der Thoraxdeformitet erhalten und eine Zunahme der Kor

perhohe um 5 5 cm gewonnen werden Die Werte fur Calcium Phophor und einer Anzahl von Spurelementen wurden vor und während der Behandlung untersucht und werden besprochen Die Erfahrung aus diesem Falle unterstutz die Ansicht dass orale Phosphatbehandlung einen Platz in der Behandlung von hypophosphatämischer Osteomlazie hat

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RÉSUMÉ

Il est décrit un cas très grave d ostéomalacie hypophosphatémique non *héréditaire* avec glucosurie rénale compliquée de résection gastrique chez un jeune homme de 27 ans Les premiers symptômes se sont manifestés à l âge de 18 ans A 26 ans le malade était gravement invalide après une perte de hauteur du corps de 16 5 cm le développement d une deformité thoracique et une myopathie proximale marquée Après un an de traitement avec de fortes de vitamines D de phosphate et de calcium il était entièrement remis Au moyen d un traitement par extension orthopédique pratiquée durant l état ostéomalacique une certaine correction de la déformité thoracique a été obtenue avec une récupération de 5 5 cm de la hauteur du corps Les métabolismes du calcium du phosphore et d un nombre d autres éléments ont été étudiés avant et pendant le traitement et sont discutés L expérience acquise de ce cas soutient le point de vue que le phosphate oral a une place dans le traitement de l ostéomalacie hypophosphatémique

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EPIDURAL ANAESTHESIA IN LOW BACK PAIN AND SCIATICA

By

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INTRODUCTION

Low back pain and its treatment form a complex problem. Conservative measures are manifold, most of which have in common that the long term results are in general questionable. For temporary relief, however, alleviation of pain can be obtained in various ways of which e.g. epidural injections of either local anesthesia, corticosteroid preparations or saline separately or a combination of either compound have attracted some interest (*Sehgal*, *Gardner* 1960, *Coomes* 1961, *Davidson*, *Robin* 1961, *Mack* 1964).

Caussade & Queste (1909) reviewed some cases in which they had used amylocaine hydrochloride with good results. A more thorough investigation was published by *Evans* (1930) who injected procaine and saline epidurally and claimed acceptable results in 22 of 40 patients with sciatica. Satisfactory effect was reported by *Kelman* (1944) who had carried out 486 injections in 116 patients with sciatica; 8 of these were cured, 41 markedly improved, 45 moderately improved and 17 only had slight improvement whereas 5 remained unchanged.

Cyriax (1957) advocated epidural anaesthesia as the conservative method of choice for patients with low back pain. Those presenting neurological signs were treated in the same way.

Coomes (1961) has made a comparison of two groups of 20 out-patients with sciatica, one of which was treated with epidural injections of 50 ml 0.5 per cent procaine, the other with bedrest only. He found that pain relief was obtained in the epidural group within 11 days whereas the bedrest group needed 31 days for recovery.

Other agents than local anesthesia have been used for epidural in-

jections and in 1961 Davidson & Robin reported on 28 patients with sciatica who received large volumes (average 72 ml) of saline epidurally They believed that nerve root pain was caused by the nerve root being compressed by hypertrophic tissue and adherent to it They ascribed the successful results in their investigation to be due to the mechanical disrupture of adhesions In their investigation with saline only as injection fluid 4 were permanently cured and 16 obtained temporary relief In 8 patients the injection had no effect Of these 5 had a *prolapsed disc and the return of symptoms after injection was* explained by the nerve root being stretched over the prolapsed tissue Temporary relief was however observed and this was thought to be due to a high hydrostatic pressure acting on the root After absorption of the injected fluid the pathological situation was retained as before and thus pain returned

Normally there is a negative pressure in the epidural space According to *Lindahl* (1952) this disappears in association with sciatica This disappearance was postulated as a symptom of an exsudative inflammatory process Corticosteroids injected epidurally have been claimed *to yield satisfactory results (Sehgal, Gardner 1960 Mack 1964 Jacoby* 1966 *Hanse* 1966)

In 1960 Brown reported on 20 patients in whom he injected first saline and following this 40 mg hydrocortisone tertiary butylacetate and 40 mg of prednisolone 21 phosphate either separately or in combination 84 per cent improved with excellent and good results No untoward effects were noted

The technique by which the epidural injection is performed also attracts some interest In 1962 Eriksson reported on long term epidural anaesthesia by a plastic catheter in the epidural space for 3 days In these patients numbering 21 a mixture of local anaesthetic and hydrocortisone was injected 16 patients improved within 5 days and could go back to work in about 11 days

The rationale behind the effect of this treatment is obscure It may be unwise to advance any theory of action but it may be worth mentioning the views of *Swerdlow & Mark* (1961) who think that the variation of the extent and duration of analgesia in epidural injections may depend on expanse of epidural space size of escape routes level of injection volume of solution injected speed and pressure of injection

The object of this paper was to investigate the results of epidural anaesthesia in patients with low back pain and sciatica

MATERIAL

This study comprises 48 patients (Table 1) all of whom received extradural injection treatment on 117 occasions

Table 1 Age and sex

Age	Male	Female	Total
20–30		1	1
31–40	5	5	10
41–50	13	6	19
51–60	7	6	13
61–70	4	1	5
Total	29	19	48

Of these 30 had not been operated at the time of the injection treatment whereas 18 who had previously been operated were treated for residual symptoms The types of pain in both the non operated and operated groups were low back pain without irradiation and with sciatica Tables 2 and 3

Table 2 Diagnosis for injection treatment in non operated group

Sex	Low back pain				Total
	without irradiation		with sciatica 2–3 months		
	2 days–one week	3–7 months	right	left	
♂	1	7	4	6	18
♀	1	4	4	3	12
Total		11	8	9	30

Table 3 Diagnosis for injection treatment in operated group

Sex	Low back pain					Total
	without irradiation		with sciatica 3–4 months			
	2 days–one week	3–7 months	right	left	both	
♂	3	2	2	3	1	11
♀	2	2	1	1	1	7
Total	5	4	3	4	2	18

This investigation has only been concerned with registration of loss of pain in connection with epidural injections and no special reference has been made to neurological abnormalities or the straight leg raising test. From the results the patients in the different groups were classified as experiencing complete, *moderate* or no relief of pain. Recordings were made immediately after injection by the anaesthetist and then on each consecutive day by the surgeon for at most one week. Checks were also made at the follow up clinic. Final registration was made one or two years after injection treatment.

METHOD

All patients were premedicated with 25 mg promethazine (Lergigan®). Prior to the injection 2 mg phenyl ephrine was given intramuscularly to prevent fall in blood pressure. The epidural anaesthesia was performed with the patient lying on his side. The level of injection was either L III–L IV or L V. The extradural space was identified by the loss of resistance technique (Sicard Forestier). After a test dose of 2–3 ml of anaesthetic fluid had been given 2–3 min were allowed to elapse to be sure that no spinal anesthesia accidently ensued. The decided amount of the anaesthetic was then injected. As anaesthetic 1 per cent mepivacaine (Carbocain®) was used in most of the cases. In 3 cases the 2 per cent solution was injected. In 3 patients 25 mg hydrocortisone was admixed to the anaesthetic. The volume of anaesthetic was around 20 ml. However in 7 instances less than 15 ml were given, in 5 patients more than 30 ml were injected. 117 epidural blocks were given to 48 patients. 16 patients were given one block each. One patient received 9 blocks in periods for 8 months. The other patients were treated two or three times in periods up to two weeks. Single injection technique was used in all the cases.

RESULTS

The immediate effect of the epidural block was sensory loss and a sensation of heat in the lower part of the body. Motor paralysis was not always present which may be due to the concentration of the anaesthetic solution being weak.

Non Operated Group at Time of Injection

The pain sensation disappeared during the time of anaesthesia in all but five cases. When the anaesthesia receded pain returned in all patients. In 2 patients there was a gradual relief of pain to complete alleviation within one and two weeks respectively after the acute onset. At follow up two years later both patients were pain free. In one patient the alleviation was moderate after two months and has remained so two years later. In 22 patients the periodicity in the course of low back pain was in no way affected by the injection treatment (Table 4).

The 5 patients who did not experience any relief of pain during the

anaesthesia were later operated In two a prolapsed disc was excised These two patients recovered completely In the remaining three no prolapse was found but scar tissue was observed to fix the nerve root to the posterior part of the intervertebral disc After operation no relief of pain was recorded and a new series of epidural injections was instituted Two recovered completely within 3 to 6 months respectively and are keeping well after 2 years The patient who recovered in three months had received cortisone in combination with the anaesthetic The third patient has not yet recovered two years after the final injection treatment

Table 4 Results of injection treatment in non-operated group

Relief of pain remaining at 2 years follow up		
Complete	Moderate	None
6	1	23
(four operated after injection)		(one operated after injection)

Operated Group

Eighteen patients received injection treatment because of pain despite previous surgical treatment at which a prolapsed disc was disclosed in nine although there was no prolapse in the remaining nine patients If at surgery a prolapse was found it was removed If no prolapse was seen the disc was not excised No cases fused at this first intervention

In the prolapsed disc group six have had no relief of pain but can carry out easier work Of these two were reoperated for a recurrent prolapse but did not experience any relief of pain Of the remaining three one has improved completely six months after injection treatment and two moderately after three and eight months respectively In the no prolapse group one patient recovered moderately whereas the remaining eight have not improved (Table 5)

Table 5 Results of injection treatment in operated group

Finding at operation	Relief of pain			Total
	Complete	Moderate	None	
No prolapse		1	8	9
Prolapse	1	2	6	9
Total	1	3	14	18

COMPLICATIONS

Side effects were very few: those recorded included headaches, fall of blood pressure and intradural administration of the drug. In two patients technical difficulties arose, which resulted in failure to obtain analgesia.

In three patients the anaesthetic was deposited intradurally. In one of these this was accompanied by a fall in blood pressure to about 60 mm Hg which was rapidly brought to normal. All three patients experienced headache lasting for 12–24 hours.

Despite prophylactic administration of metoxedrin in connection with the first few ml of anaesthetic a fall in blood pressure was registered in 12 patients to 100 mm Hg and below. On adequate treatment this was normalized in 10–15 min. and no further untoward effects were noted.

COMMENT

The object of epidural injection treatment in lumbago is alleviation of pain. Judging from various reports, however, the postulated mechanism for this varies. Some believe in the local anaesthetic breaking the noxious circle of pain temporarily, which may be all the patient needs to pass over into a state of more permanent relief (*Eriksson* 1962).

In an extensive experimental study in dogs on the dynamic factor in spinal cord compressions *Olsson* (1958) stated: "If now and then a small amount of disc tissue is pressed out through a rupture in the annulus fibrosus by active or passive movements of the spine, the inflammatory reaction and subsequent irritation of the cord will persist together with clinical symptoms. Even very large protrusions may not cause symptoms if they are firm and do not continue to enlarge — Through its inflammatory effect a dynamic factor seems to be more responsible for the maintenance of symptoms than the actual compression — Any treatment which will eliminate the dynamic factor and thus reduce the inflammatory reaction seems to be of greater therapeutic value than direct surgical removal of the protrusion."

Corresponding views have previously been offered by *Lindahl & Rexed* (1950) based on a study on histologic changes in the nerve roots of cases operated for sciatica.

The influence of a local anaesthetic on an inflamed and irritated nerve root besides the pure neural block is still unknown. In normal peripheral nerves local anaesthetics slow down the intraneural microcirculatory events and also cause a vasoconstriction of arterioles and

venules (*Hansson* 1966 *Lundberg* 1966) It is difficult to understand how an agent which causes a circulatory impairment under normal conditions can combat inflammation and bring about a longstanding relief of pain apart from the pure nerve block which follows the application of the local anaesthetic

In our hands epidural injections of local anaesthetics have not proved as successful as reported elsewhere and the rationale of it may be questioned

SUMMARY

The results of epidural injection of local anesthetics in cases of low back pain with and without irradiation have been reviewed

One group of 30 patients had not been operated prior to injection treatment The other group of 18 patients was treated for residual symptoms after previous surgery for a prolapsed disc in nine and in the remaining for a suspected but not operatively verified prolapsed disc

In all 117 injections were administered to the 48 patients

Results in non operated group Six experienced complete relief of pain Of these 4 were operated after injection treatment as this did not alleviate pain One had moderate relief Twenty three had no relief Of these one was operated after injection treatment

Results in operated group One experienced complete relief of pain three moderate and fourteen no relief

RESUME

Les resultats d injections epidurales d anesthesiques locaux dans le cas de douleurs lombaires avec ou sans irradiation ont ete reexamins

Un groupe de 30 malades n avait eas ete opére avant l injection Un autre groupe de 18 malades avait été trait pour cause de symptomes restes a la suite d interventions chirurgicales pour hernie discale dans 9 cas et pour les autres malades chez lesquels on soupçonnait une hernie discale qui ne s etait toutefois pas verifiee a l operation

En tout 117 injections ont éte administrees a ces 48 malades

Resultats pour le groupe des non-opérés Chez six les douleurs ont entièrement disparu Parmi ceux ci 4 avaient ete operes apres le traitement par les injections celui ci n ayant pas supprime la douleur Chez l un il y avait eu un soulagement modéré 23 n ont eprouve aucun soulagement Parmi ceux-ci l un a ete opere apres le traitement par les injections

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Resultats dans le groupe des operes Un a eté entierement libere de ses douleurs trois moderement et 14 n ont éprouve aucun soulagement

ZUSAMMENFASSUNG

Die Ergebnisse von epiduralen Injektionen in Fällen von Lumbago mit und ohne Ausstrahlung wurden durchgesehen

Eine Gruppe von 30 Patienten waren vor der Injektionsbehandlung nicht operiert worden Die andere Gruppe von 18 Patienten wurden wegen zuruckbleibenden Symptomen nach vorhergehendem chirurgischen Eingriff wegen Diskusprolaps in neun und bei den übrigen wegen eines vermuteten aber bei der Operation nicht sichergestellten Diskusprolaps behandlet

Insgesamt wurden 117 Injektionen an die 48 Patienten verabreicht

Ergebnisse in der nichtoperierten Gruppe Sechs hatten ein vollstandiges Verschwinden der Schmerzen Von diesen wurden 4 nach der Injektionsbehandlung operiert da diese die Schmerzen nicht erleichterte Ein Patient hatte eine massige Erleichterung Dreiundzwanzig fuhlten keine Erleichterung Von diesen wurde einer nach der Injektionsbehandlung operiert

Ergebnisse in der operierten Gruppe Einer erfuhr vollstandiges Verschwinden der Schmerzen drei eine massige Besserung und vierzehn wiesen keine Besserung auf

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Figure 1 Lateral view of the right os calcis with the vertical irregular sclerotic line

lar to the long axis of the calcaneous The sclerotic line is located between the calcaneal tuberosity and the posterior articular surface for the talus

DIAGNOSTIC PROBLEMS

Tenderness of the heel starting without trauma and with the typical x ray findings may be reminiscent of early osteoid osteoma and osteosarcoma Usually the osteosarcoma is very seldom localized to the calcis If there is any doubt about the diagnosis surgical intervention is necessary

TREATMENT

The main treatment of the stress fracture of the os calcis is to instruct the patient to avoid long walks standing jumping running or stooping A plaster cast can give comfort The cast should be used for 4–6 weeks

CASE HISTORY

A 43 year old nurses aid was seen at the outpatient clinic at the Orthopaedic Hospital in Aarhus in August 1967 (case histor no B 149 ?57) For 6 weeks she had noticed slight swelling of the right ankle No known trauma For a week the right ankle and heel had been painful Examination revealed a slight swelling of the lateral malleolar region no haematoma and normal range of movement. X rays showed a vertical fracture line between the calcaneal tuberosity and the posterior articular surface for the talus (Figure 1) A plaster cast was applied

DISCUSSION

Earlier publications (1 4) give the impression that stress fractures of the metatarsal bones were the most common stress fractures In 1967

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From the Orthopaedic Hospital, Aarhus, Denmark
(Head: Professor Eivind Thomasen, M.D.)

STRESS FRACTURE OF THE OS CALCIS

By

Søren Pilgaard

Received 13.XII.67

There is no earlier report of stress fractures of the os calcis from Scandinavia. The incidence is proved to be very high in a series of 300 stress fractures among young soldiers in basic training in the army of the U.S.A. *Darby* (2) reported the incidence as 13.0 per cent. In an earlier report from the German Army Hospitals only four of 590 stress fractures were observed in the os calcis (4). In a series of 70 stress fractures *Carlson & Wertz* (1) found only one in the calcaneus. Larger series of stress fractures have been reported without respect to the total number of stress fractures in all sites. *Winfield & Dennis* (3) reported 42 calcaneal stress fractures in 31 patients. Judging from the literature, the calcaneal fracture is worth remembering when the patient complaints of calcaneodynia.

CLINIC

The histories are, according to *Darby* (2), invariably similar. Pain in the involved heel within hours or days of prolonged exercise. The pain is usually not completely disabling as the patient often continues his work for weeks before seeing a doctor. There is no known trauma to the heel involved. The patient usually walks with a slight limp with the tender heel elevated from the ground. The heel is tender, often with some swelling also in the area of the malleolus. There is no discoloration.

X-RAYS

Immediately after the onset of the symptoms the X-ray shows no abnormality. After 2–3 weeks a repeated X-ray examination will show definite changes (Figure 1), usually a linear sclerotic zone perpendicu

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From the Hospital for Special Surgery affiliated with The New York Hospital – Cornell Medical Center New York New York

INFLUENCE OF GROWTH AND TRAUMA ON BONE MASS AND MINERAL TURNOVER IN RATS

By

Bo E R Nilsson & Paul D Saville

Received 2 viii 67

Loss of bone mineral in fractured limbs of rats has been demonstrated by *Bohr & Sorensen* (1950) *Bauer* (1954) *Bohr* (1955) and others

This loss was not confined to the fractured bone but occurred also in the neighbouring bones The loss of bone mineral was associated with an increased uptake of bone seeking radionuclides which was believed to reflect an increased bone formation rate that compensates for the resorption caused by the fracture In preliminary experiments in this laboratory it was not possible to obtain any measurable change in the mineral content either of the femur following fracture of the tibia or in the tibia following fracture of the femur in rats When comparing our data with those of other investigators it was found that the body weights of the animals in our experiments were much greater than those of the previous investigators so that our rats had reached a weight where growth was slow while previous investigators had used animals around 150 g when growth is rapid

The purpose of the present study was to investigate the effect of growth on post traumatic osteopenia in the rat

MATERIAL AND METHODS

One tibia (left or right at random) was fractured under aether anesthesia in twenty nine male Sprague Dawley rats of the Charles River strain At the time of fracture the animals ages ranged from 26 to 78 days (approximate weight range 50–300 g) Thirteen days following fracture they were injected sub cutaneously with about two microcuries of Strontium–85 and twenty four hours later two weeks following fracture they were killed. The femora from the fractured and the control limbs were

cleaned of soft tissue and the fresh bone was weighed suspended from a fine copper wire in distilled water at 4 C mopped dry and re weighed in air The volume was calculated as the difference between these two weights The bones were then ashed at 600 C for forty eight hours and the ash weighed Radioactivity was measured in a well scintillation detector to a precision of 1 per cent and expressed as a per cent of the injected dose

RESULTS

The ash weight of the femora on the fractured side was less than that of the control femora (Figure 1) Moreover the specific ash weight (g ash/cc bone) was less on the fractured side (Figure 2) The volume of the femur on the fractured side was also less than that on the control side (Figure 3) When ash weight on the control and the fractured sides was plotted as a function of the bone volume there was no significant difference between control and fractured (Figure 4) Thus even though the femora on the fractured side had less total ash than the controls the ash content for any given volume was the same in both groups

The total uptake of the isotope was less in the femora on the fractured side than in the femora of the control side (Figure 5) but the specific activity was higher on the fractured side (Figure 6) Specific activity (Figure 7) was found to be a negative function of specific ash weight (density) in the femora on the fractured side as well as the

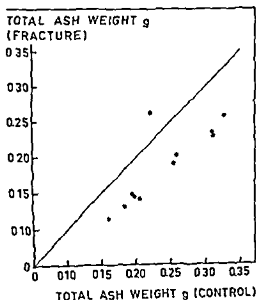
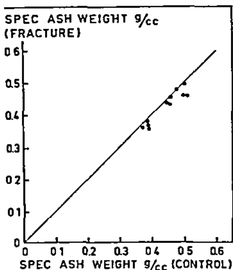


Figure 1 Total ash content of the femora on the fractured side is plotted against total ash content of the femora on the control side All except one point fall below the horizontal line indicating that the ash content of the control femora is greater than that on the fractured side

Figure 2 Specific ash weight in the fractured femur is plotted against specific ash weight in the control femur All except one point fall below the oblique line indicating that the specific ash weight on the control side is greater than that on the fractured side



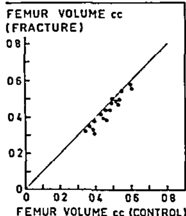


Figure 3 Femur volume on the fractured side is plotted against femur volume on the control side All points fall below the oblique line indicating that femur volume was always greater on the control side

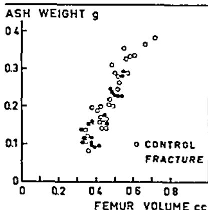


Figure 4 Ash weight of the femora is plotted against femur volume for the control and the fractured sides There is clearly no significant differences between the two sides

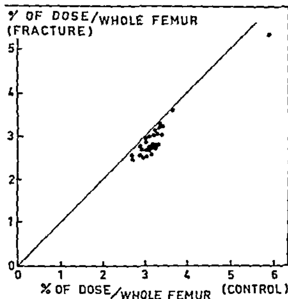


Figure 5 Total radioactivity in the femur of the fractured side is plotted against total radio activity on the control side All points fall below the oblique line indicating that radioactive up take is always greater in the control femora

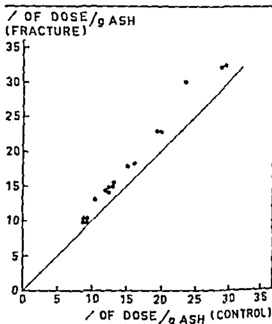


Figure 6 Specific activity in the fractured side was plotted against specific activity in the femora on the control side In this case all the points fall above the oblique line indicating that the specific activity is always greater in the femora on the fractured side

control side Analysis of covariance revealed no significant difference between these two regressions so that for any given specific ash weight the specific activity was the same on the fractured side as on the con trol side Actually the specific activity tended to be higher in the control

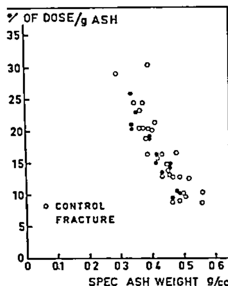


Figure 7 Specific activity in the control and fractured femora is plotted against specific ash weight The negative linear regressions so formed are calculated by the method of least squares and compared by analysis of covariance there is no significant slope or intercept difference (0 05 $<P<$ 0 1)

DISCUSSION

When the above investigators demonstrated that the tibia ipsilateral to a fractured femur had less ash than the control tibia as well as a higher specific activity they assumed that this was evidence of post traumatic osteopenia with a compensatory increase in bone formation rate However it has subsequently been shown that the femur density increases linearly with body weight in the rat and also with femur volume (*Saville & Smith* 1966 *Smith & Saville* 1966) We have shown that the femur ipsilateral to the fractured tibia is smaller than the control femur but has the appropiate ash content and isotope uptake for its volume Moreover the specific activity is also appropiate for bones of their volume and density In short what seems to have happened is that following fracture growth has slowed down in the femur ipsilateral to the fracture but not in the contralateral femur The apparent changes in mineral content and uptake of isotope are nothing more than the difference between smaller and less dense bones compared with larger and denser ones All the bones were normal with respect to both density and isotope uptake for bones of their volume

Therefore it may be concluded that the twenty four hour uptake of Strontium-85 in rat bone is not merely a function of bone formation rate but also reflects bone density or variables related to bone density

This phenomenon may be explained by an exchange process which occurs more rapidly in the smaller and less dense bones

SUMMARY

The ash content the volume and the twenty four hour Strontium 85 uptake were measured in the femora of rats two weeks after fracture of one tibial shaft The decreased mineral content of the femur ipsi lateral to the fractured tibia was possible to explain by unilateral cessation of growth in the femur of the fractured limb The ash con tent and twenty four hour isotope uptake were the same on the two sides when bone volume and density were held constant

In this experiment specific activity twenty four hours following injection of Strontium 85 was best correlated with femur density and *may not be regarded entirely as a parameter of bone formation rate*

RESUME

La teneur en cendres le volume et l absorption pendant 24 heures de Strontium 85 ont été mesurés dans le fémur de rats deux semaines après une fracture d un tibia La diminution de la teneur en minéral du femur du meme coté que le tibia fracturé fournit peut être l explica tion de la cessation unilatérale de la croissance du fémur dans le mem bre fracturé La teneur en cendres et l absorption d isotope pendant 24 heures sont identiques des deux cotés lorsque le volume et la densité de l os sont maintenus constants

Dans cette expérience l activité spécifique dans les 24 heures qui suivent l injection de Strontium 85 est plutot en relation avec la densité du femur et ne doit pas etre considérée entièrement comme le para mètre du taux de la formation osseuse

ZUSAMMENFASSUNG

Der Aschengehalt das Volumen und die vierunzwanzigstundige Stron tium 85 Aufnahme wurden in Femuren von Ratten zwei Wochen nach Bruch eines Tibiaschaftes gemessen Der herabgesetzte Mineralgehalt des Femurs ipsilateral zur gebrochenen Tibia konnte durch das ein seitige Aufhören des Wachstums am Femur des gebrochenen Gliedes erklärt werden Der Aschengehalt und die vierundzwanzigstundige Aufnahme von Isotopen waren die gleichen auf beiden Seiten wenn Knochenvolumen und dichtigkeit konstant gehalten wurden

In diesem Versuch war spezifische Aktivitet die 24 Stunden nach der Injektion von Strontium 85 auftrat am besten mit der Dichtigkeit des Femurs verbunden und sollte nicht vollständig als ein Massstab der Knochenbildungsgeschwindigkeit angesehen werden

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Acta orthop Scandinav 39 280-290 1968

From the Orthopaedic Hospital Dept I Copenhagen (Head A Bertelsen) and the Institute for Experimental Research in Surgery University of Copenhagen (Head H H Wandall)

ON THE DEVELOPMENT OF THE EPIPHYSIS OF THE FEMORAL HEAD FOLLOWING DISLOCATION OF THE HIP JOINT IN YOUNG RABBITS

By

H Bohr K Baadsgaard & Ph Sager

Received 6 xii 67

INTRODUCTION

In a previous paper (*Bohr, Baadsgaard & Sager* 1965) it was shown that dislocation of the hip joint in new born rabbits results in interruption of the vascular supply to the femoral head and ischemic necrosis of the epiphyseal bone During revascularization it was demonstrated that vessels from the metaphyseal side perforated the epiphyseal plate with the formation of temporary bone bridges between the meta and epiphysis Upon the disappearance of these perforations within the first 4 weeks following the dislocation only little disturbance in the development of the epiphyseal bone was seen showing that sufficient blood supply was established

The present investigation deals with the development and structural changes in the epiphyseal bone after dislocation of the hip joint in one week old rabbits studied by means of Tetracycline labelling and micro radiography

MATERIAL AND TECHNIQUE

One week old rabbits had the right hip dislocated through gentle manipulation with pressure on the adducted femur A slight click was felt at the dislocation which was confirmed on X ray photos The animals moved freely and were able to support themselves on both legs shortly after the dislocation In one experiment 7 rabbits

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of two different litters had an injection of "Reverin" (Pyrrolidino-methyl tetra cyclin) 12.4 mg subcutaneously either on the day before dislocation of the hip or at different days after dislocation. In another experiment 6 animals from one litter had an injection of "Reverin" 12.5 mg subcutaneously the day before dislocation and some of the animals had a further one or two injections of "terramycine" (Oxy tetracycline) 12.5 mg subcutaneously on different days following the dislocation as seen in the table where the animals have been arranged according to age at sacrificing.

The animals were killed by an overdose of Nembutal and permanent dislocation of the hip was controlled on X ray photos of the intact animals. A careful dissection of the hip joints was performed with observations of the deformities and the development of the head and the neck of the femur as well as the acetabulum. Following removal of the femur X ray photos of the femoral head were made and after fixation and dehydration the proximal part of the femur was embedded in Methyl methacrylate. Sections were cut in the frontal plane with a rotating saw and after grinding under water to a thickness of 50 μ microradiography was performed using a Machlett X ray tube A.E.G. 50 supplied with a Wolfram anode generated at 12 kV and 10 mA. Exposures were made on Kodak Spectroscopic plates 649-0 at a film focus distance of 15 cm and with an exposure time of 10 min. The sections were then mounted on glass slides with "Depex" and the fluorescence in ultraviolet light observed using secondary Reichert filters OG1 and GG9. Two or three sections of each specimen were examined.

Table 1

Animal No	Label before disloc	Label after disloc	Killed after disloc	Semicircular "ring" from label before disloc
1	0	R. 1 day	2 days	
2	R. 1 day	0	3 days	+
3	R. 1 day	0	6 days	+
4	R. 1 day	0	7 days	—
5	0	R. 7 days	9 days	
6	R. 1 day	T. 9 days	10 days	+
7	R. 1 day	0	11 days	0
8	0	R. 9 days	13 days	
9	R. 1 day	T. 9 + 13 days	14 days	0
10	0	R. 13 days	15 days	
11	R. 1 day	T. 13 + 17 days	18 days	0
12	R. 1 day	T. 18 + 22 days	24 days	0
13	R. 1 day	T. 24 + 28 days	35 days	0

Labelling of animals with Reverin (R) and Terramycin (T).

The results are indicated as presence (+) or absence (0) of semicircular fluorescent "ring" corresponding to enchondral ossification before the dislocation of the hip joint.

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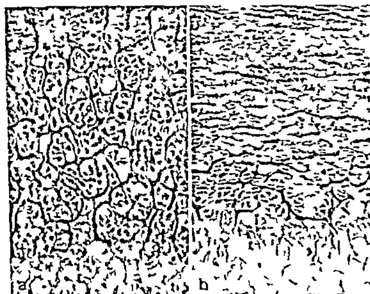


Figure 2 a Phase contrast photo of the articular cartilage of the right femoral head in animal No 3 showing increased layer of hypertrophic cartilage cells Magnification × 1?0

Figure 2 b Phase contrast photo of the articular cartilage of the left femoral head (control sid) in animal No 3 Magnification × 1?0

out visible signs of persisting vessels On radiographs the epiphyseal bone of the dislocated femoral head appeared distinctly diminished and showed some sclerosis during the first two weeks after dislocation but later regained normal size although with a somewhat deformed shape

From fluorescence microscopy it can be seen that the uptake of Re verin in the epiphyseal bone the day before dislocation remains almost undisturbed in the femoral head during the following week Thus the previous enchondral ossification below the articular cartilage persists in the right femoral head as a semicircular fluorescent ring while this ring disappears in the normal epiphysis of the left femoral head due to continued growth (Figures 1a and 1b) Despite the inhibition of ossification processes it can be seen that the articular cartilage of the right femoral head increases in thickness as compared with the control side This is due to proliferation of the cartilage cells with formation of an increased layer of hypertrophic cells in the stage preceding enchondral ossification (Figures 2a and 2b)

At the beginning of the second week following dislocation revascular



Figure 6 Fluorescent photo of the right femoral head in animal No 9 labelled with Reverin the day before dislocation of the right hip and with Terramycin 9 and 13 days later Sacrificed 14 day after dislocation It is evident that the semicircular fluorescent ring from Reverin is broken and that enchondral ossification has been resumed Magnification × 12

persistence of the fluorescent ring corresponding to the enchondral ossification during labelling the day before dislocation (Figure 1a) With revascularization ossification is resumed in conformity with the vascular contribution to osteogenesis (*Trueta* 1962), and bone formation takes place primarily as creeping apposition on the old trabeculas resulting in an increased density of the epiphyseal bone (*Bobechko & Harris* 1960 *Hulth* 1961 and *Bohr & Larsen* 1965) In the case of a young growing organism an image of the original epiphyseal bone is left inside the new developed bone giving the appearance on X ray photos of a head within the head (*Salter* 1966) Such an image may be either positive or negative depending on whether appositional or resorption processes prevail In the present investigation a positive "head in the head can be observed during the time when the semicircular "ring from the previous enchondral ossification remains (Figure 5a) With the disappearance of this ring a negative head in the head is seen due to the increased resorption (Figure 7a) During the following period new bone trabeculas are formed and the structure is normalized although some deformity of the femoral head may result The observation that proliferation of the cells of the articular cartilage continues despite devascularization of the epiphyseal bone supports previous findings (*Bohr, Baadsgard & Sager* 1965 and *Slutis & Rokkanen* 1966) and indicates that independent nutrition of the growing cartilage may take

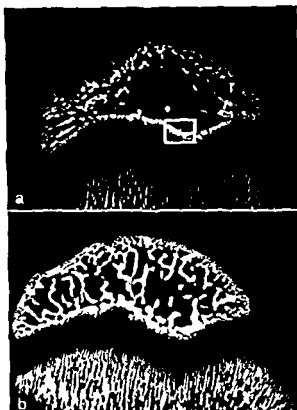


Figure 7 a Microradiograph of the right femoral head in animal No 19 sacrificed 24 days after dislocation of the right hip Osteoporosis and defects of the original epiphyseal bone can be seen Magnification × 10

Figure 7 b Microradiograph of the left femoral head in animal No 19 Magnification × 10

place probably from the synovial fluid (*Ingelmark* 1950 *Ekholm* 1951 and *Brower Akahoshi & Orlic* 1962)

These results may be compared with the dyplastic changes in the femoral head which occur in relation to congenital dislocation of the hip joint in humans where the phenomenon of a "head within the head is often observed From the evidence of the present investigation the appearance of a positive or a negative head in the head may be ex plained owing to impairment of the vascular supply to the femoral head



Figure 8 *Fluorescent photo of the right femoral head in animal No 12 corresponding to the enframed area on Figure 7 a Small fragments of bone diffusely labelled with Reverin before dislocation of the right hip are left inside depositions of new bone between lines of Terramycin labelling 18 and 27 days after dislocation Magnification × 50*

SUMMARY

In one week old rabbits dislocation of the right hip joint with disruption of the vascular supply to the femoral head was performed and the development and structural changes of the epiphyseal bone were studied by means of Tetracycline labelling and microradiography The results compared with the normal development on the control side show that the ossification processes stop leaving the previous enchondral ossification undisturbed during the following week although the proliferation of the cells in the articular cartilage proceeds With revascularization 1–2 weeks after dislocation partly through vessels perforating the epiphyseal plate reconstruction of the epiphyseal bone takes place Primarily an increased density of the epiphyseal bone is seen due to appositional bone formation This is followed by osteoporosis with defects due to resorption of the original epiphyseal bone and with disappearance of the previous enchondral ossification line The course of events is discussed in relation to the phenomenon of a "head within the head" seen following congenital dislocation in humans

RESUME

Chez des lapins âgés d une semaine il a été ...
l articulation droite de la hanche avec ...
vasculaire à la tête fémorale afin d étud...
changements structuraux de l os epiphysaire ...
a la tetracycline et de la microradiographie ...
developpement normal du coté de contrôle ...
de l ossification s arrete laissant l ossification ...
inchangés durant la semaine suivante ...
lules dans le cartilage articulaire ...
tion 1–2 semaines après la dislocation ...
perfore la plaque épiphysaire une ...
commença Primairement on observa une ...
physaire due a une formation osseuse ...
d ostéoporose avec des defauts dus a la ...
original et a la disparition de la ligne d ...
eure Il est discuté de l evolution du process ...
a l interieur de la tete observée après une ...
les humains

ZUSAMMENFASSUNG

Bei eine Woche alten Kaninchen wurde ...
Huftgelenkes mit Unterbrechung der Gef...
ausgeführt und die Entwicklung und Str...
physenknochens mittels Tetracyklinm...
studiert Die mit der normalen Entwickl...
glichenen Resultate zeigen dass der Oss...
dass die vorgehende enchondrale Ossifik...
Woche ungestort belassen wird während ...
im Gelenkknorpel fortschreitet Mit ...
Wochen nach der Verrenkung beginnt ... l
senknochens teilweise durch Gefäss ... d
bohren Anfänglich wird eine erhöhte ... ied
wegen übermässiger Knochenbildung ... one
Osteoporose mit Defekten wegen Re... them
physenknochens und unter Verschwin... (8) in
dralen Ossifikationslinie Der Verlauf ... is pro
zunahme auf die Erscheinung des ... the sec
man nach angeborener Hüftverrenk... ce they

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Acta orthop Scandinav 39 291-30? 1968

From the Department of Orthopaedics (Head O Lindahl) and Diagnostic Radiology (Head G F Saltzman) the University Hospital, Umeå Sweden

MEASUREMENT OF THE DEFORMITY IN SCOLIOSIS

By

Olof Lindahl & Anders Movin

Received 31 x 67

Two major difficulties encountered in assessing the results of treatment for idiopathic scoliosis are firstly the impossibility of knowing the future spontaneous course when active measures are taken and second ly the uncertainty incurred in the measurement of the deformity The former difficulty implies that some regression of the deformity must occur before it is possible to ascertain the effect of the treatment or else one half of the patients must remain untreated so as to provide a control group—an unattractive alternative

If the regression is only of moderate degree more accurate methods for measuring the deformity are required than are at present available

THE DEFORMITY IN SCOLIOSIS

The magnitude of the deformity in scoliosis is almost invariably asses sed on the basis of the primary curve in a frontal view The measure ment of this curve on the film is usually performed by either *Cobb s* (1) or *Ferguson s* (4) method

In the former the difference between the angle of the upper and lower surface of the upper and lower vertebrae respectively is measured (Figure 1) whereas *Ferguson* determines the angle between the mid points of 3 vertebrae in which the upper and lowermost are defined by what is taken to be the primary curve and the third vertebra is one midway between them—or if there are two it will be one of them (Figure 2) Another method has been evolved by *Tidestrom* (8) in which the angular deviation of each vertebra is determined thus pro viding a general representation of the magnitude and extent of the sco-liosis (Figure 3) The three methods are basically equivalent since they

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Figure 2 As in Figure 1 but the angles measured by Ferguson's method Scoliosis angles then 36



Inclination of the upper surfaces of the vertebrae

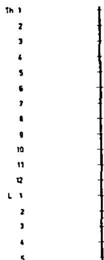


Figure 3 As in Figure 1 Registration of scoliosis angles by Tidestrom's method The same scoliosis as in Figures 1 and 2

sidered but it is well known that small differences in setting the X ray tube and in rotating the patient give different projections and hence different angles Such changes in angle comply with the principles of solid geometry which however are fairly difficult to apply in practical work It has been found by *Bergquist & Sevastikoglou* (7) that small changes in the direction of projection can result in changes in the scoliosis angle of up to 11 per cent

The main sorce of error in determining the scoliosis angle is the lack of reproducibility of the projections from one occasion to another The reason for this lies in the difficulty of defining the frontal plane and determining it clinically in cases of scoliosis especially severe ones

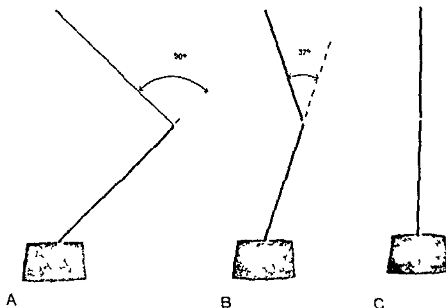


Figure 4. A steel wire bent through 90° (A). The scoliosis angle diminished as the wire is rotated (B). When it has been rotated through 90° (C) it is seen as a straight line.

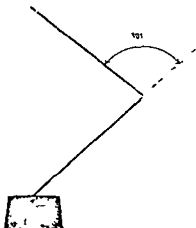
owing to the marked deformation of the abdomen. Because of the rotation that accompanies the scoliosis the maximum curvature does not lie in the frontal plane. The angle reproduced in the frontal film will therefore be too small by an amount that will depend on the discrepancy between the frontal plane and the plane containing the maximum angle.

As in the development of scoliosis the plane containing the maximum angle changes because of the rotation, the error in the determination of the frontal plane will be supplemented by that incurred by the change in the plane of the maximum angle. After an operation to reduce this rotation it will be difficult, if the difference is only moderate, to ascertain by conventional methods whether or not the scoliosis angle has increased.

The determination of the *maximum scoliosis angle* and the deviation of its plane from the frontal plane is superior to conventional procedures for obtaining an impression of the deformations, and if the methods of determination are reproducible it should be possible to make a comparison from one occasion to another.

It should be borne in mind that in the determination of the *maximum*

Figure 5 As in Figure 4 but the wire is inclined forwards so that the scoliosis angle is increased



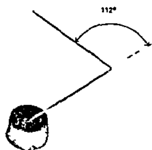


Figure 6 As in Figure 4 The wire is neither inclined nor rotated but the camera is placed above the level of the vertex of the angle the scoliosis angle is then increased

angle one is measuring a combination of pure scoliosis and kyphosis (or lordosis) This however is probably not a disadvatage

On the basis of a mechanical theory of the origin of scoliosis *Lindahl* has resected transverse processes and later on such processes and the posterior part of the ribs on the concave side of the scoliosis (5 6) The result of this was chiefly to reduce the rotation of the thorax rather than the scoliosis angle This angle was then measured by Ferguson s method and the usual radiologic technique

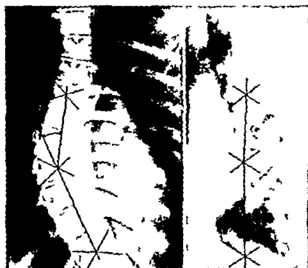


Figure 7. Idiopathic scoliosis as represented by the direct method. Right.—The scoliosis is seen as a straight line. Left.—Plane perpendicular to that of the right figure, the scoliosis angle then being projected to give its maximum value (33°).

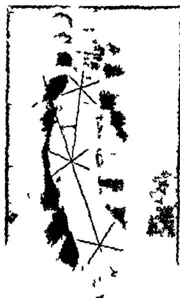


Figure 8. As in Figure 7, but with the scoliosis depicted on a conventional frontal film. The scoliosis angle is then 27° (—22 per cent).

To obtain a more accurate estimate of the way and the degree to which the scoliosis is affected by these measures, a new radiologic technique has been evolved by which it is possible to measure the maximum scoliosis angle and the plane of this angle in relation to a vertical plane through the two iliac spines.

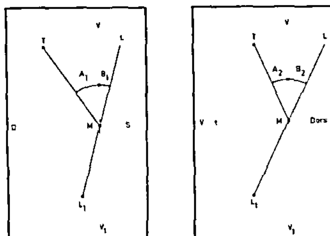


Figure 9 *Diagram showing measurement of scoliosis angle by the mathematical method Left—Film in the same plane as the iliac spines Right—Film perpendicular to the former To calculate the maximum angle the scoliosis angle TML is divided into the components A and B on each side of a vertical line (VV_1)*

METHOD

Two alternative methods were evolved

The Direct Method

The patient is examined erect by fluoroscopy (oblique lateral projection) and rotated so that the scoliosis disappears and the spine is projected straight and *vertical* The maximum scoliosis angle is then obtained with projection at right angles to the former and with the patient's position unchanged

It is then also possible to measure directly the angle between this plane and a vertical plane containing the two spines Accurate apparatus for measuring this angle is required

The Mathematical Method

From the scoliosis angles measured on two perpendicular projections of the spine (arbitrary planes) it is possible by applying the principles of solid geometry to calculate (*i*) the maximum scoliosis angle and (*ii*) the angle between the plane containing the maximum angle and any of the planes of the projections It is convenient to take one of the planes as that passing through the iliac spines The solid geometry technique has been developed and applied to radiology by *Edholm* (2 3) By means of a stereo instrument (designed by him and manufactured by Kifa Stockholm) it is quite a simple matter to determine angles without the need to resort to the otherwise inevitable mathematical calculations

An advantage of this method is that the influence of any inclination of the spine to the vertical, or any adjustment above or below the maximum curvature is

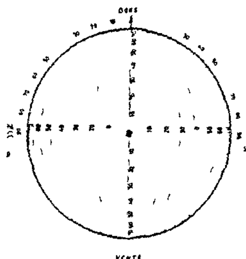


Figure 10. Edholm's stereo-instrument. Dx, Sin, Ventral and Dorsal are marked.

automatically corrected for and there is no need to seek the position in which the scoliosis curve is projected as a straight line.

MEASUREMENT OF ANGLES

A complete account of the theory underlying the measurement of angles in radiologic examinations is provided in Edholm's monograph (2). It will suffice here to outline the principles for the measurement of scoliosis angles. Figure 4 depicts a steel wire bent through a right angle. If the ends of the arms of the angle are held one vertically above the other the scoliosis angle will be seen to *decrease* as the object is rotated about an axis passing through the two ends (B). The maximum angle (90°) is obtained when the film is perpendicular to the plane containing the arms of the angle (A). On rotation through 90° from this position (C) the wire is seen as a straight line (the scoliosis angle is zero).

In Figure 5 the same wire is seen when no rotation is performed but the ends of the arms of the angle are inclined to the vertical. An inclination perpendicular to the direction of projection (to the sides) does not affect the size of the angle but an inclination in the direction of the central ray (forwards or backwards) results in a gradual *increase* in the angle.

Figure 6 shows the effect of altering the direction of the central ray above or below the actual apex of the angle. The rotation is the same throughout and there is no inclination in the vertical plane. This produces an *increase* in the scoliosis angle in both directions.

When the direct method is used it is necessary to eliminate these errors through controlled changes in position of the patient and the X-ray tube but with the mathematical method the error in setting is corrected automatically in calculation of the angle.

PRACTICAL PROCEDURE

We use a focus to film distance of 140 cm and the patient is required to hold his arms above his head with the elbows bent. Vertical cassettes with grids are used in both projections.

When the direct method is used only one accurate setting is required as a rule, any correction of the forward—backward inclination of the back being effected by fluoroscopy. In the projection that is perpendicular to the plane for which the scoliosis curve is reproduced as a straight line and *vertical* the maximum or true scoliosis angle is then obtained directly (Figure 7). In a conventional frontal film (Figure 8) the scoliosis angle will in this case be 7 smaller and it is difficult to reproduce this projection in repeated exposures. In the case of smaller changes of this frontal scoliosis angle one therefore never knows for certain whether the compared films are taken identically as regards rotation.

When the mathematical method is used the actual X-ray examination is simpler to perform. Only 2 perpendicular projections are obtained one of which is taken parallel to the two iliac spines. The lower edge of both X-ray films shall be horizontal. The central ray should pass through the middle vertebra in the scoliosis curvature. The only difficulty is then to calculate the required angles.

Figure 9 shows a scoliosis angle drawn with two perpendicular projections. The image on the left is in the same plane as the two spines (almost a frontal film) and that on the right is perpendicular to the former (practically a lateral film). In both projections the line 1–1, corresponds to the perpendicular through the middle vertebra (*M*).

To calculate the maximum scoliosis angle the scoliosis angles in the two projections must be divided into two, one on each side of the vertical, here designated A_1, A, B_1 and B. These are oriented in different

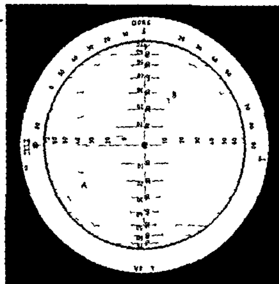


Figure 11 Fdholm's stereo instrument The coordinates for the maximum scoliosis angle have been entered with the guidance of the two values for A and B

directions A_1 to the right (Dx) and A ventrally and B_1 and B to the left (Sin) and dorsally respectively

If the angles are measured on the films in question the following values are obtained

Component angles		Scoliosis angle in the respective projections
A_1 = 35	dx	58 in the frontal film
A = 23	ventral	
B_1 = 15	sin	47 in the lateral film
B = 27	dorsal	

From these values the required angles can then be obtained with *Fdholm's* stereo instrument

This instrument is shown in figure 10 and the 4 directions dx sin dorsal and ventral are drawn in on the instrument In the following calculation the top transparent disk is provided for marking with a pencil and the middle disk is rotated 90 with respect to the bottom one

Figure 11 shows how the angles are drawn in on the instrument is in a coordinate system A_1 and B_1 are set off on the meridians of the middle disk and A and B along the meridians of the bottom one The value of A_1 which has the direction Dx is set off in the direction "Dx on the instrument and A which has the direction Ventral downwards The intersection of the coordinates gives the point A In the same

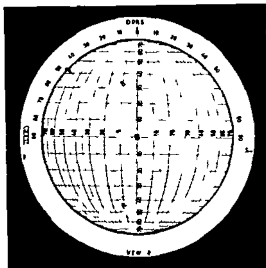


Figure 12 Edholm's stereo instrument The points A and B on the top disk have been rotated so as to lie on the same meridian of the bottom scale The maximum scoliosis angle can then be read off on the vertical scale in the bottom disk The rotation of the plane containing the maximum scoliosis angle is indicated by the arrow

way the point B is entered To obtain the maximum angles A and B the top disk on which the points are marked is rotated so that the points lie on the same meridian of the bottom scale (Figure 12)

On the vertical bottom scale it is then possible to read off these maximum angles (here 28 and 38) The maximum scoliosis angle is thus 66 (28 + 38) To reach this position it is necessary to rotate the top disc 47 counter clockwise and this angle (47) corresponds to the plane of the maximum angle in relation to the sagittal plane (a plane perpendicular to that through the two iliac spines)

For a full account of the stereo instrument and the underlying mathematical theory the reader is referred to *Edholm's* paper By means of the instructions given here it is possible to obtain the required angles without understanding the underlying theory

In the cases in which the direct and mathematical methods were compared they showed close agreement and it would seem that either of them provides more accurate complete and reproducible information on the deformation in scoliosis than the conventional procedures

SUMMARY

The authors have evolved two X ray methods by means of which it is possible to determine in different ways the maximum scoliosis angle and the angle between a frontal plane through the iliac spines and the plane containing the maximum angle This technique enables a high

level of reproducibility to be obtained in the determination of the angles on different occasions. This is difficult with the usual technique where frontal films are not defined and therefore not reproducible.

RESUME

Les auteurs ont développé deux méthodes radiologiques au moyen desquelles il est possible de déterminer de différentes manières l'angle maximum de la scoliose et l'angle entre un plan frontal à travers les épines iliaques et le plan contenant l'angle maximum. Cette technique permet dans la détermination des angles à différentes occasions d'arriver à un degré élevé de reproduction, ce qui est difficile avec la technique ordinaire, les films frontaux n'étant pas définis et par conséquent impossibles à reproduire.

ZUSAMMENFASSUNG

Die Verfasser haben zwei Röntgenmethoden entwickelt, mittels derer es möglich ist, in verschiedener Weise den maximalen Skoliosewinkel und den Winkel zwischen einer Frontalebene und einer Ebene im maximalen Winkel zu bestimmen. Diese Technik ermöglicht es, ein hohes Niveau von Reproduktionsfähigkeit bei der Bestimmung von Winkeln bei verschiedenen Gelegenheiten zu erhalten. Dies ist schwierig mit der gewöhnlichen Technik, bei der Frontalfilme nicht genau bestimmt und daher nicht reproduzierbar sind.

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LUMBOSACRAL SYNOVIAL JOINTS IN FLEXION EXTENSION

By

CARL HIRSCH & THORD LEWIN

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INTRODUCTION

Subluxation of lumbar synovial joints in narrowed discs has been reported by several investigators (*Williams* 1932 *Johnson* 1934 *Lange* 1936 *Oppenheimer* 1937 *Hadley* 1935 1936 1951 and 1961 *Baumann* 1957 and others) It has mostly been claimed to occur in lumbo sacral segments *Harris & Macnab* (1954) defined subluxations as follows

"A line was drawn on a lateral X ray through the inferior border of the vertebral body If the top of the facet from the underlying vertebra was found a few millimeters above that level a subluxation was recognized (Figure 1)

Other authors (*Hadley* 1935 and 1961 *Keller* 1953 *Baumann* 1957) have identified subluxation as a contact between the upper edge of a S 1 facet and the L 5 pedicle in the intervertebral foramen (Figure 2) When these areas are forced against each other a dense contour is seen in lateral X rays This is called impingement In autopsy specimens with osteoarthritis in synovial joints and marked disc degeneration impingement has also been verified as a wider shaped upper facet area causing a dense radiographic appearance (*Hadley* 1935 and 1961 *Baumann* 1957)

The normal anatomy of lumbosacral joints has recently been studied in autopsy material (*Lewin* 1967) The most distal parts of L 5 pedicles are found in the intervertebral foramen lateral to the top of an S 1 facet This means that the S 1 facet can move medially to the L 5 pedicle Therefore in a lateral X ray the upper section of a S 1 facet will be projected upon the pedicle High S 1 facets can occur as a normal variable



Figure 1 Lumbosacral interspace The height of the disc is normal Macroscopically the disc is graded as degenerate The synovial joints had no evidence of osteoarthritis The picture is taken in flexion The distal border of the L 5 vertebra is indicated The top of the S 1 facet reaches the borderline of L 5

Figure 2 The same specimen as in Figure 1 now in extension The S 1 facet has a high position Its upper border points towards the medial deepening of the pedicle at the junction of the laminar isthmus

Abnormal motion in the lumbar spine is often seen in synovial joints in extreme positions It has been stated that it may indicate degenerative changes either in discs or joints Impingement has been described as a possible cause of low back pain (*Keller* 1953 and 1962) Various manipulative procedures for correction of the positions of the facets have been discussed It was therefore felt worth while to study the lumbosacral junction in flexion and extension in specimens with and without disc degeneration or osteoarthritis in synovial joints With this in mind attempts were made to answer the following questions

1 To what extent are the positions of S 1 facets in flexion and extension affected by degenerative changes in discs or joints at the lumbosacral junction?

2 Is the range of motion in lumbosacral synovial joints altered by degenerative changes?

3 Do radiographic studies of synovial joints indicative of disturbances in the pattern of motion in lumbosacral junctions justify conclusions about the pathomorphology?

MATERIAL AND METHODS

This study is based on 42 lumbar spines from routine autopsies The subjects ages ranged from 20 to 80 years The age and sex distribution is seen in Table 1

Table 1 Age and sex

Age	20–45 years	45–80 years	
	16	9	25
	10	7	17
	26	16	42

The specimens were removed from the body of Th XII to the sacrum and freed from musculature The sacrum was fixed in a vice Lateral roentgenograms were taken of the spines in flexion extension and in normal resting position The specimens were moved in a strict sagittal direction allowing the spines to assume an extreme position in either direction

Disc degeneration was recorded and graded by gross anatomical evaluation after the discs had been cut horizontally (*Friberg Hirsch* and *Schajowic*) Discs with structural changes strictly confined to the nucleus pulposus and not attended by loss of disc height were accepted as normal Degeneration was classified as annulus ruptures with or without loss of original fibre elements

In one subgroup the size of the interspace was unaffected in the other it was narrowed The synovial joints were studied microscopically Osteoarthritis was said to exist if the cartilage of the facets had decreased in thickness and additional bony changes such as osteophytes or subchondral alterations were seen

In flexion the upper border of the S 1 facet as demonstrable in the lateral X ray film A line was drawn on L 5 between the anterior and posterior distal edges of the vertebral body (Figure 1) In extension the projection of the upper point of the S 1 facet relative to the distal border of the L 5 pedicle was noted (Figure 2)

RESULTS

Flexion

In flexion (Table 2) the highest point of the S 1 facet was found above the distal border of L 5 in 17 cases below in 13 and at the same level in 12 In two thirds of the spines where the level of the S 1 facet

was high (10/17) no disc degeneration or osteoarthritis was present More than one third of the specimens with low S 1 facets had narrowed interspaces (5/13 Table 3) Osteoarthritis was found only in those synovial joints where the top of the S 1 facets was higher than or the level of the line through the distal border of L 5 However of all cases recorded as high or at the same level less than one fourth had osteoarthritis (8/29 Table 2)

Table 2 Position of S 1 facets in flexion

Facet position	Disc and joint pathology OO	DO	OA	DA	Total
Low	8	5	0	0	13
Level	5	4	1	2	12
High	10	2	1	4	17
Total	23	11	2	6	42

OO = normal disc no osteoarthritis
DO = disc degeneration no ostroarthritis
OA = normal disc osteoarthritis
DA = disc degenartion and osteoarthritis

Table 3 Position of S 1 facets in flexion of unaffected and of narrowed lumbosacral disc interspaces

Facet position	Disc interspace Unaffected O	Unaffected D	Narrowed D	Total
Low	8	0	5	13
Level	6	4	2	12
High	11	3	3	17
Total	25	7	10	42

O = normal disc D = disc degeneration

Extension

In 22 of the 42 specimens when tested in extension the upper point of the S 1 facet was seen above the distal contour of the L 5 pedicle (Table 1) The discs and joints were normal in all of the 22 The same incidence of high S 1 facets was found when the disc space was nar

rowed with or without synovial joint osteoarthritis (5/10 Table 5) In spines with normal lumbosacral discs and joints high facets were noticed in about half of them (11/23 Table 4)

Table 4 Position of S 1 facets in extension

Facet position	Disc and joint pathology				
	OO	DO	OA	DA	Total
Low	12	5	0	3	20
High	11	6	2	3	22
Total	23	11	2	6	42

Table 5 Position of S 1 facets in extension of unaffected and of narrowed lumbosacral disc interspaces

Facet position	Disc interspace			
	Unaffected		Narrowed	
	O	D	D	Total
Low	12	3	5	20
High	13	4	5	22
Total	25	7	10	4

Range of Motion

It is evident that the *position* of the S 1 facet varies both in normal and degenerate spines and does not indicate the morphology present It was therefore felt that the range of movement of the synovial joint should be measured during maximum flexion and extension

The figures presented in Table 6 were obtained by using the upper surface of the sacrum as a reference plane in the determination of the position of the L 5 facet For all measurements the mean values ± twice the standard deviation was between 4 and 8 mm

When the estimated figures in a given case fell outside this range the movement in a particular joint was considered increased or de creased

Increased facet motion was noticed in 3 cases with no disc degenera tion or osteoarthritis and in one case with only osteoarthritis

Limitation of motion occurred only in the osteoarthritic group (4/8) According to the hypothesis of equal distribution between groups d-

was high (10/17) no disc degeneration or osteoarthritis was present More than one third of the specimens with low S 1 facets had narrowed interspaces (5/13 Table 3) Osteoarthritis was found only in those synovial joints where the top of the S 1 facets was higher than or the level of the line through the distal border of L 5 However of all cases recorded as high or at the same level less than one fourth had osteoarthritis (8/29, Table 2)

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In 22 of the 42 specimens when tested in extension the upper point of the S 1 facet was seen above the distal contour of the L 5 pedicle (Table 4) The discs and joints were normal in all of the 22 The same incidence of high S 1 facets was found when the disc space was nar

were found between normal and degenerative spines which could be used to predict pathomorphological changes in discs or synovial joints

One may question the tenability of these findings and conclusions Differences in deformation between normal and degenerated discs under static loads have been shown to be significant but small (*Hirsch* 1954 *Nachemson* 1963 *Rolander* 1966) This in itself would mean that although one would expect some changes in the pattern of synovial facet positions they might not be measurable in lateral roentgenograms especially since differences in facet positions are commonly found in normal spines

The range of motion in the lumbosacral synovial joint was measured Disc degeneration did not affect the excursion of the L 5 facet relative to the sacrum A decrease was noticed only in osteoarthritis which seems quite acceptable

SUMMARY

Lateral X rays were taken of 42 lumbar spines removed at routine autopsy The roentgenograms were taken with the spine in full flexion and extension and in the normal resting position From these X rays the position of S 1 facets was determined The fifth lumbar discs were cut horizontally for macroscopical evaluation of degenerative changes and the synovial joints of the lumbosacral segment were studied microscopically for osteoarthritis It was found that the position of S 1 facets varied both in flexion and extension regardless of the presence of degenerative changes in discs and joints The position of the facets did not justify any conclusion about pathomorphology in the lumbosacral segment The range of joint motion was measured Disc degeneration did not affect facet excursion When the range of movement was decreased the synovial joints showed evidence of osteoarthritis

RÉSUMÉ

Des radiographies latérales de 42 colonnes lombaires prélevées au cours d autopsies routinières ont été prises en flexion et extension complète ainsi qu en position normale de repos Sur la base de ces radiographies la position des facettes S 1 a été déterminée Les disques de la cinquième vertèbre lombaire ont été coupés horizontalement afin de procéder à l évaluation macroscopique des modifications dégénératives et les articulations synoviales de la région lombo-sacrée ont été étudiées au microscope pour déceler la pr[illegible]ence d osteoarthrite On a découvert que

la position des facettes S 1 varie en flexion et en extension sans rapports avec la présence de modifications dégénératives des disques et des articulations La position des facettes ne justifie aucune conclusion concernant la pathomorphologie de la région lombo sacrée La mobilité de l articulation a été mesurée et elle n est nullement affectée par la dégénération du disque En revanche en rapport avec une limitation du mouvement on a constaté la présence d une osteoarthrite dans les articulations synoviales

ZUSAMMENFASSUNG

Laterale Rontgenaufnahmen von 42 Lendenwirbelsäulen die von Rutineautopsien erhalten worden waren wurden in voller Beugung und Streckung sowie in normaler Ruhelage vorgenommen Von diesen Rontgenbildern wurde die Lage der S 1 Facetten bestimmt Die funften Lendenwirbeln wurden zur makroskopischen Bewertung von degenerativen Veränderungen horizontal geschnitten und die Synovialgelenke des lumbosakralen Segmentes wurden zum Nachweis von von Osteoarthritis mikroskopisch studiert Man fandt dass sich die Position der S 1 Facetten bei Beugung und Streckung unabhängig von der Gegenwart degenerativer Veränderungen in Disken und Gelenken veränderte Die Lage der Facetten erlaubte keinerlei Schlusse hinsichtlich der Pathomorphologie im Lumbo sakralsegment Das Ausmass der Gelenkbewegung wurde gemessen Diskusdegeneration beeinflusste den Bewegungsausschlag der Facetten nicht Wenn eine Bewegungseinschränkung vorkam dann zeigten die Synovialgelenke Zeichen von Osteoarthritis

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From the Orthopaedic Hospital Copenhagen Dept 1 and 2 (Heads A Bertelsen and Hj Larsen) and Dept of Radiology (Head M Schalimtzek)

COMPARATIVE STUDY OF MYELOGRAPHIC FILLING DEFECTS IN ROOT SHEATHS AND OPERATIVE FINDINGS IN CASES OF SUSPECTED LUMBAR INTERVERTEBRAL DISC HERNIATION

By

K. Skou Andersen & Otto Steppen

Received 8 III 67

In 1931 *Arnell & Lidström* introduced the water soluble contrast medium Abrodil in myelography. However the new method did not acquire practical significance until about 15 years later when *Arnell* (1944 1948) and *Lindblom* (1946) had worked out a technique by which they demonstrated the numerous advantages of the method and reduced its untoward side effects to an acceptable minimum

In Scandinavia and later in several European centres myelography using water soluble contrast medium thereafter became the routine method for visualizing the lower part of the dural sac and the cauda equina Therefore this form of myelography may now be assessed on the basis of a fairly comprehensive material (*Lewison* 1947 *Johanson* 1950 *Knutsson* 1951 *Andresen* 1953 *del Buono* 1957 *Schalimt el* 1958 *Kolstad & Solem* 1959 *Amundsen et al* 1963)

One of the main advantages of water soluble contrast medium above the previously used iodized oils is that it clearly visualizes the root sheaths thus facilitating a myelographic diagnosis of lateral disc herniations

Arnell (1948) and *Lindblom* (1948) have studied the anatomical background of the myelographic picture of the root sheaths They found the subarachnoid space of the root sheaths to vary widely in shape and extent from patient to patient and in each individual case there might be a certain asymmetry without amounting to morbid changes According ly the normal myelographic appearances of the root sheaths may

vary within wide limits and deficient of a root sheath need not necessarily mean a morbid condition in or around the nerve root concerned

Where a filling defect in the root sheath represents not only a congenital variation in development but a morbid condition there are various aetiological possibilities viz disc herniation spondylosis spondylolisthesis scar changes following previous operations sequelae of arachnoiditis tumours or sequelae left by fractures of the spine (*Knutsson* 1947 *Arnell* 1948 *del Buono* 1957 *Walk* 1958 *Kolstad & Solem* 1959 *Cronqvist* 1959)

In many cases a straight X ray film of the spine supplemented by myelographic examination will afford sufficient differential diagnostic certainty so that the nature and site of the disease may be deduced from a comparison of the radiological and clinical findings But often a filling defect in a root sheath is the main or at times the only radiographic finding

In the by now comprehensive literature on myelography using water soluble contrast medium there does not seem to have been any analysis of the diagnostic significance of the deficient root sheath filling on the basis of a clinical material Accordingly we felt that it would be of interest to investigate by comparing the myelographic root sheath appearances with the findings at operation in a group of patients with presumed disc herniations why the filling of the root sheath was deficient

MATERIAL

During the period January 1959 to April 1966 748 myelographies were done in the Orthopaedic Hospital Copenhagen on patients whose clinical symptoms and signs indicated disc herniations of one or more of the 3 caudal lumbar discs

The myelographies were carried out by the technique of *Lenson* (1947) The contrast medium used was 20 per cent Conturex (= Myelotrast Skiodan) (methiodal sodium)

The classification of the cases was based upon the reports of the radiologist and the surgeon in the case sheets

As far as the myelographic appearances of the root sheath are concerned a distinction will be made between 2 forms of filling defect *viz* faint filling and shortening The assessment of the intensity of the contrast as well as of the length of the root sheath was based upon comparison with the symmetrical root sheath Where a faintly filled root sheath was also shortened the case was assigned to the shortened group

Analysis of the 748 myelographies disclosed 229 cases in which a filling defect in a root sheath had been described and in which the nerve root concerned had been inspected at subsequent operation These 229 cases make up the present material

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COMPARATIVE STUDY OF MYELOGRAPHIC FILLING DEFECTS IN ROOT SHEATHS AND OPERATIVE FINDINGS IN CASES OF SUSPECTED LUMBAR INTERVERTEBRAL DISC HERNIATION

By

K. Skou Andersen & Otto Sneppen

Received 8. III. 67

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In Scandinavia and later in several European centres, myelography using water-soluble contrast medium thereafter became the routine method for visualizing the lower part of the dural sac and the cauda equina. Therefore this form of myelography may now be assessed on the basis of a fairly comprehensive material (*Levison* 1947, *Johanson* 1950, *Knutsson* 1951, *Andresen* 1953, *del Buono* 1957, *Schalimtzek* 1958, *Kolstad & Solem* 1959, *Amundsen et al.* 1963).

One of the main advantages of water-soluble contrast medium above the previously used iodized oils is that it clearly visualizes the root sheaths, thus facilitating a myelographic diagnosis of lateral disc herniations.

Arnell (1948) and *Lindblom* (1948) have studied the anatomical background of the myelographic picture of the root sheaths. They found the subarachnoid space of the root sheaths to vary widely in shape and extent from patient to patient, and in each individual case there might be a certain asymmetry without amounting to morbid changes. Accordingly the normal myelographic appearances of the root sheaths may

Thus in the present material a faint filling of a root sheath was a fairly uncertain sign of disc herniation

Where the myelographic showed only a shortened root sheath (group B) 71 4 per cent of the operations revealed disc herniation in the site while 11 4 *per cent of the cases exhibited other morbid conditions* as a cause of the myelographic abnormality In the remaining 17 2 per cent operation showed a normal looking and free root

Thus a shortened root sheath was a fairly certain sign of herniation of a disc in relation to the nerve root

Groups C and D represent cases in which the myelography showed not only deficient filling of the root sheath but also an abnormal shape of the contrast column The operative findings therefore bore little relation to the deficient filling and are thus in this context of minor interest However the groups are of some value as a basis for comparison with groups A and B

Where the myelographic finding was not merely a deficient filling of the root sheath but also thinning of or impression into the contrast column (groups C and D) about 86 per cent of the cases showed disc herniation in relation tothe root concerned while about 10 per cent exhibited other abnormalities to explain the myelographic findings In the remaining 4 per cent the operation revealed a normal and free root

As might be expected the more pronounced myelographic changes in groups C and D were relatively often signs of disc herniation and in these groups the anatomical findings around the root were seldom normal

As is apparent from Table 1 170 cases (74 per cent) showed a disc *herniation in relation to the deficiently filled root sheath In 50* (29 per cent of these cases the root was according to the operative report extended over the herniation and in 47 cases (28 per cent) squeezed In 26 cases (15 per cent) the root was adherent while in 17 (10 per cent) it was flattened or narrowed and in 7 (4 per cent) showed diffuse or spindle shaped thickening In 46 cases (27 per cent) the report gave no details concerning the root

Another thing which appears from Table 1 is that in 33 cases (14 4 per cent) operative revealed no disc herniation but other abnormalities in explanation of the deficient root sheath filling The operative findings in these 33 cases are listed in Table 2

Table 2 shows that apart from disc herniations the most common cause of deficient root sheath fillin, was periradicular scar tissue left

Cases in which the filling defect was doubtful or in which it might have been due to technical reasons were excluded.

All the patients had undergone operation because of a suspicion of disc herniation and in all the myelogram and the clinical findings were in agreement in so far as the surgeons found in all cases indication for laminectomy or hemilaminectomy in order to inspect the root corresponding to the deficiently filled root sheath. In other words the clinical symptoms in all the cases might be imagined to be due wholly or partially to an affection of the root in question.

RESULTS

In Table 1 the myelographic and operative findings in 229 cases of filling defects are compared.

Groups A and B represent cases in which a filling defect of the root sheath was the only abnormal myelographic finding in relation to the disc concerned.

Table 1. Operative findings in 229 cases with defective root sheaths on the myelogram

Myelographs	Operative findings corresponding to the abnormal root sheath on the myelogram			Total
	Posterior herniation of the intervertebral disc	No posterior disc herniation but other abnormalities	No posterior disc herniation. Nerve root free and normal	
Group A	32 (51.6%)	16 (25.8%)	14 (22.6%)	62 (100%)
Group B	25 (71.4%)	4 (11.4%)	6 (17.[illegible]%)	35 (100%)
Group C	54 (85.7%)	4 (6.4%)	5 (7.9%)	63 (100)
Group D	59 (85.5%)	9 (13.0%)	1 (1.5%)	69 (100%)
Total	170 (74.[illegible]%)	33 (14.4%)	26 (11.4%)	229 (100%)

On the basis of the myelograms the cases are classified into the following 4 groups:

A. Faint contrast filling of the root sheath. Normal contrast column.

B. Shortened root sheath. Normal contrast column.

C. Faint contrast filling of the root sheath. Impression into the contrast column.

D. Shortened root sheath. Impression into the contrast column.

It is apparent from the table that where the only myelographic finding was a fairly faint filling of a root sheath (group A) only 51.6 per cent proved to have a disc herniation in relation to this root, while 25.8 per cent showed other abnormalities in explanation of the myelographic findings. In the remaining 22.6 per cent the operations revealed a normal and free root.

and in 2 cases where the ligamentum flavum was greatly thickened an extremely cramped space in the root canal afforded an adequate explanation of the myelographic findings

Lastly it will be seen from Table 2 that in one case operation revealed a root cyst and in another case diffuse thickening of the root In the latter case the root sheath was divided it showed considerable thickening and adhesions to the nerve fibres but these changes are unexplained

Among the total material of 299 cases 26 (11 4 per cent) showed an apparently normal and free nerve root (cf Table 1) It cannot be decided whether the myelographic appearances represented a non morbid asymmetry in the development of the root sheath or whether there was a question of a morbid phenomenon But it may be mentioned that in 12 of the 26 cases there was herniation of a disc proximally to the deficiently filled root sheath When considering the oblique course of the nerve roots it may be imagined that in some of these 12 cases the myelographic appearances were due to an influence by the named herniation upon the root in its proximal course

DISCUSSION AND CONCLUSION

The present study did not include any assessment of the diagnostic accuracy obtained by the myelographic investigation as a whole It aimed exclusively at elucidating the cause of a single component in the myelographic picture viz the deficiently filled root sheath

Now a deficient filling of a root sheath is not infrequently the only myelographic evidence of disc herniation so that assessment of this very finding may decide whether or not surgery is carried out

As might be expected on the basis of the studies of *Arnell* (1948) and *Lindblom* (1948) we found in the present material too that with a view to disc herniation the deficient filling of a root sheath was not a particularly specific sign

The diagnostic uncertainty manifests itself especially in cases where faint filling without shortening of the root sheath was *the only myelographic* finding In this connection it is remarkable that disc herniation was found in only 52 per cent of the cases while 26 per cent exhibited other periradicular abnormalities

In assessing these findings however it must be taken into consideration that in all cases the clinical symptoms might be imagined to be due wholly or partially to an affection of the root concerned On this background the frequency of disc herniation is hardly above that which

would be expected if the operation had been done on the basis of clinical findings alone. Accordingly, the relatively faintly filled root sheath is a fairly certain sign of disc herniation, which does little to support the clinical diagnosis.

Where a shortened root sheath was the only myelographic finding, operation showed in 71 per cent herniation in relation to the root and in only 11 per cent other abnormalities.

The shortened root sheath, then, is a relatively specific sign which gives good support to the clinical diagnosis of herniation.

In respect to the aetiology of root lesions not due to disc herniations the findings in the present material were in keeping with those of previous clinical studies (Table 2). For instance, *Knutsson* (1947), *Cronqvist* (1959) and *del Buono & Fuchs* (1959) found that frequently sequelae of herniation surgery manifest themselves myelographically as deficient filling of the root sheath, while *Andresen* (1953) found periradicular adhensions as an explanation of this myelographic appearance. It is known also that spondylolisthesis, osteophytes or a thickened ligamentum flavum may influence the filling of the root sheaths (*Arnell* 1948, *Johansen* 1950, *Cronqvist* 1959, *Fassbender & Stössel* 1960).

SUMMARY

In 229 cases showing deficient root sheath filling in Conturex (methiodole sodium) myelography the myelographic and operative root findings were compared. In all cases the operation was done because of a suspicion of disc herniation.

When a faintly filled root sheath was the only myelographic abnormality, 51 per cent of the patients showed herniation in relation to the root concerned (Table 1, group A).

When a shortened root sheath was the only myelographic abnormality, 71.4 per cent of the patients showed herniation in relation to the root (*Table 1, group B*).

Where deficient filling of a root sheath occurred together with an abnormal contrast column, 86 per cent of the cases had disc herniation in relation to the root (Table 1, groups C and D).

The operative findings in 33 cases with root lesions unrelated to disc herniation are listed in Table 2.

It is concluded that a faint filling of a root sheath can only to some extent support a clinical diagnosis of disc herniation, while a shortened root sheath is a relatively specific sign of disc herniation.

RESUME

Dans 299 cas examines a la myelographie Conturex (methiodole sodium) qui montraient un remplissage deficient d une gaine de racine rachidienne les trouvailles myelographiques et operatoires ont ete comparees Dans tous les cas l operation a ete pratiquee parce qu on suspectait une hernie discale

Lorsque la gaine d une racine rachidienne etait faiblement remplie 51 6 pour cent des malades presentant cette anomalie avaient une hernie en relation avec la racine impliquee (Tableau 1 groupe A)

Lorsque le raccourcissement de remplissage d une gaine de racine rachidienne etait la seule anomalie 71 4 pour cent des malades avaient une hernie discale en relation avec cette racine (Tableau 1 groupe B)

Lorsqu une gaine defectuesement remplie a ete observee en meme temps qu un contraste anormal dans la colonne 86 pour cent des malades avaient une hernie discale en relation avec cette racine (Tableau 1 groupes C et D)

Les trouvailles operatoires dans 33 cas de lesion de racines rachidiennes n ayant aucun rapport avec une hernie discale sont rapportees sur le Tableau 2

Il est conclu qu un faible remplissage d une gaine de racine rachidienne ne peut appuyer qu a un certain degre le diagnostic clinique d une hernie discale alors qu un raccourcissement de la gaine d une racine rachidienne est un signe specifique de la hernie discale

ZUSAMMENFASSUNG

In 299 Fällen die mangelhafte Wurzelscheidenfüllung bei der Conturex (Methiodole Natrium) Myelographie zeigten wurden die myelographischen und operativen Wurzelbefunde verglischen In allen Fällen wurde die Operation wegen des Verdachtes einer Diskushernie vorgenommen

Wenn eine schwach gefulte Wurzelscheide die einzige myelographische Anomalie war zeigten 51 6 Prozent der Patienten Hernienbildung im Verhältnis zu der betroffenen Wurzel (Tafel 1 Gruppe A)

Wenn eine verkürzte Wurzelscheide die einzige myelographische Anomalie war zeigten 71 4 Prozent der Patienten Hernienbildung im Verhältnis zur Wurzel (Tafel 1 Gruppe B)

Wo magelhafte Fullung zusammen mit einer abnormalen Kontrastsaule auftraten hatten 86 Prozent der Fälle eine Diskushernie im Beziehung zur Wurzel (Tafel 1 Gruppen C und D)

Die operativen Befunde in 33 Fällen mit Wurzelschädigungen ohne Beziehung zu einer Diskushernie sind in der Tafel 2 angeführt.

Man schliesst, dass eine schwache Füllung einer Wurzelscheide nur bis zu einem gewissen Grade die klinische Diagnose einer Diskushernie unterstützen kann, während eine verkürzte Wurzelscheide ein verhältnismässig spezifisches Zeichen einer Diskushernie ist.

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WEDGE OSTEOTOMY OF SPINE IN ANKYLOSING SPONDYLITIS

By

HANS EMNEUS

Received 21.iv.67

Severe ankylosing spondylitis often leads to complete ankylosis of the spine, sometimes with pronounced kyphosis. The kyphosis is due, among other things, to the patient sleeping with too many pillows under his head because of the nocturnal pain.

Extreme kyphosis causes thoracic and abdominal pain and, what is more, limitation of the distance the patient can see ahead of him. Sometimes the axis of vision is directed almost perpendicular to the ground. In such cases the patient cannot use busy thoroughfares.

Smith-Petersen, Larsson & Aufranc (1945) were the first to describe wedge osteotomy of the spine. Since then several large series have been published by Herbert of Aix-le-Bain and others. *La Chapelle* (1946) used a two-stage procedure: first wedge osteotomy from behind through the spinous processes and arches and, after an interval of some weeks, chiselling through the vertebra or dividing the anterior longitudinal ligament from an anterior approach.

Herbert (1955) has performed 42 wedge osteotomies in various parts of the spine, including 3 in the cervical region, 1 in the upper thoracic region, 9 in the lower thoracic region and the rest in the lumbar region. In 10 cases he used the two-stage procedure. Complicating paraplegia occurred in 3 cases, in 2 of which it disappeared after decompression, while in the third it persisted and the patient died.

Briggs, Keats & Schlesinger (1947), *Law* (1949) and *Adams* (1952) preferred immediate correction on the operating table as well as fusion. *Kallio* (1963) reported 1 case in which he performed a one-stage operation with immediate correction and fixed the spinous process with a loop made of a long piece of skin.

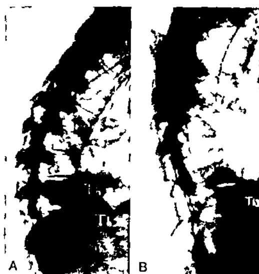


Figure 1 A Case 1 Thoracic spine before operation The pseudarthrosis is located between Th XI and XII

Figure 1 B Case 1 Thoracic spine 3 weeks after osteotomy Observe how the pseudatrthorsis has functioned as part of the wedge osteotomy



Figure 2 A Case 5 Lumbar spine before operation Observe the assumed pseudarthrosis just above the middle of the reproduction

Figure 2 B Case 5 Lumbar spine after osteotomy Observe how the osteotomy has been done The pseudarthrosis was not true but only apparent The disk was immovable Therefore the vertebrae was chiselled through from behind and the spine corrected

From 1950 to 1962 five patients were subjected to wedge osteotomy at Lund always because the patients were unable to look forward The patients also had other symptoms such as respiratory difficulties abdominal discomfort and pain but not sufficient to indicate operation Candidates for osteotomy must be selected very carefully for rehabilita

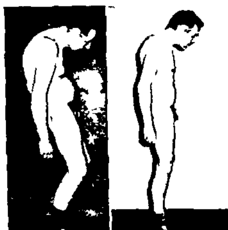


Figure 3 Case 1 before operation (left) and 10 months after osteotomy (right)

tion requires a long time In other words the operation should be considered only when it has much to offer

The 5 osteotomies were performed as one stage operations with a wedge osteotomy posteriorly and then gradual redresssement in a plaster cast for 3 weeks

What we found useful in the one stage operation was that some patients had a pseudarthrosis between two vertebral bodies of the otherwise ankylotic spine Such pseudarthosis may perhaps be due to a fracture of the bamboo spine

In all of the cases such a pseudarthrosis could be observed and we performed the osteotomy at that level We found however that the "pseudarthrosis was not always true but only apparent See Figures 2A and 2B

The operation requires patience on the part of the surgeon Two thirds of the circumference of the dural sac must be exposed To judge the size of the wedge we used stainless steel plates of 15 20 and 30 Dural injury could be avoided in 4 of the 5 cases The escape of fluid in the 5th case was not troublesome and caused no secondary complication Anaesthesia may be problematic General anaesthesia is not satisfactory since the patient is prone during the operation and since the thoracic cage is completely rigid Intubation is practically impossible Local anaesthesia may be used but it places large demands on the patient We have found extradural anaesthesia very satisfactory and it is probably the best method available for such patients The case reports are given in Table 1

It is clear from the Table that the postoperative period of immobili

Table 1

	Age sex Year of operation	Interval between onset of disease and op (yr)	Level of osteotomy and anaesthesia	Redressement period after op (wk)	Immob in plaster cradle (wk)	Plaster corset (mth)	Improvement in angle	Postop compl	Interval between op and review and results
1	43 yrs ♂ 1950	9	Th XI–XII local	6 weeks	15	9 months	25	Spasmodic pain Slight lip cyanosis	11 yrs Very satisfied no disability Angle of vision decreased a few degrees
2	47 yrs ♂ 1951	27	L I–L II local	3 weeks	7	5 months	20	Slight abdominal discomfort	8 yrs Very satisfied no disability Angle of vision decreased a few degrees
3	43 yrs ♂ 1958	13	Th XI–XII local	3 weeks	12	6 months	30°	Slight decubitus over sacrum	7 yrs Very satisfied Felt very well first years Then arthritis of hips Disability pension
4	32 yrs ♂ 1962	13	L III–L IV extradural	3 weeks	11	5 months	20	Sec pseud arthros Reop with fusion 18 months later	3 yrs Satisfied Works after vocational training Sedentary occupation Angle of vision decreased a few degrees
5	42 yrs ♂ 1962	12	L I–L II extradural	3 weeks	12	7 months	24	Meteorism	2 yrs Very satisfied Works as a clerk No decrease of angle of vision

Case 1 and Case 2 reported by Wil rg C (195) Nord Med 48 1530

sation is long 7–15 weeks in a plaster cast including 3 weeks for redressement and then the use of a plaster corset for 5–9 months Complications occurred in one patient (Case 4) who developed pseudarthrosis at the site of the osteotomy when he was recumbent the spine was relatively straight but when he stood up it flexed 20 and he was thus unable to look ahead 1½ years after first surgery he was reoperated upon and fused with an iliac graft and bone chips He is now able to do certain kinds of work All of the 5 patients are satisfied with the result of the operation

Patient No 3 developed arthritis of the hip 2 years after the operation but nevertheless considered that the improvement of the axis of vision was extremely valuable Patient No 3 is the only one who cannot work and who has therefore been granted a disability pension

SUMMARY

In patients with a bamboo spine extreme kyphosis and consequent downward direction of the axis of vision wedge osteotomy of the spine may be indicated The operation places large demands on the surgeon s patience but is not hazardous The rehabilitation period is long but all 5 patients operated upon in Lund between 1950 and 1962 are more than satisfied with the relief the operation has given

RESUME

Chez les malades ayant une colonne vertébrale en forme de bamboo extrême cyphose et par consequent une inclinaison de l axe de vision une ostéotomie en coin de la colonne peut être indiquée L operation requiert beaucoup de patience de la part du chirurgien mais elle n est pas hasardée La periode de traitement est longue mais tous les 5 malades opérés à Lund entre 1950 et 1962 ont été extrêmement satisfaits du soulagement que l opération leur a apporté

ZUSAMMENFASSUNG

Bei Patienten mit einer Bambuswirbelsaule extremer Kyphose und folgender Abwartsrichtung der Sehachse kann Keilosteotomie der Wirbelsaule angezeigt sein Die Operation erfordert grosse Geduld von seiten des Chirurgen ist aber nicht gefährlich Die Wiederherstellungszeit ist lang aber alle 5 Patienten die zwischen 1950 und 1962 in Lund operiert

wurden sind mehr als zufrieden mit der Erleichterung die ihnen die Operation gebracht hat

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UNILATERAL JUVENILE MUSCULAR ATROPHY OF UPPER LIMBS

By

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Received 13.XII.67

In 1959 *Hirayama* and co-workers (1) drew attention to a new clinical entity of juvenile muscular atrophy of unilateral upper limb based on their experience of 12 cases. In 1963 *Hirayama* and co-workers (2) reported a more detailed study including laboratory tests of 11 of the 12 and of 9 new patients. Early onset localized muscular atrophy of one arm, the disease is progressive in the one arm for some years and then becomes stationary. This form of muscular atrophy is distinctly different from any other entities of muscular atrophy hitherto described. In 2 patients *Hirayama* and co-workers (1, 2) found hyperactive deep reflexes of the leg on the affected side. This paper describes a typical case, the symptoms and the diagnostic problems.

CASE REPORT

A 23-year-old male undergraduate (engineer) was admitted to the out-patient clinic at Orthopaedic Hospital in Aarhus on February 28, 1966. A few weeks before admission he had been found unfit for military service because of selective atrophy of the right upper arm.

The young student, who had never been in hospital before, now wanted to be examined.

His family history was noncontributory. During school age he had been healthy. 8 years ago he started to work as an electrician apprentice and already the first winter he noticed that he fumbled when using a small screw-driver, and occasionally he unintentionally dropped the screw-driver—he was right handed. Occasionally he had been aware of a fine tremor of the fingers of the right hand, especially when he was working with small objects. When it was cold the right hand was stiff and felt cold. He had no pain or paraesthesia. Three years previously, when he started his education as an engineer, he was aware of a slight progressive weakness of the grip of his right hand and he felt some trouble in using a pencil for more than 3–4 hours

without a rest He had no pain in the neck or trouble with the left hand or his lower limbs The past 2 years he had not noted any progression or changes on the affected side

Two years ago he had an attack of dizziness after he had been working for 5 hours at the drawing table He stayed in bed for a week and was bothered by some dizziness for 3 months followed by jerks of the head He has not have any such attack since no headache no tinnitus or disturbances of vision he cannot recall any spell of fever or the possibility of polio myelitis He still uses the right hand more than the left

Examination on February 28 1966 revealed a well nourished and healthy looking young man with considerable atrophy of all intrinsic muscles of the right hand The right thenar eminence was atrophic There was decreased power of abduction of all the fingers Some weakness of the flex prof to the IV and V finger together with weakness of the flexor pollis longus and brevis There was slight paresis of the extensor carpi ulnaris muscle The other muscles of the right arm and shoulder girdle were normal

There was a slight asymmetry of the face without changes of the mimic muscles or the sternocleido mastoid muscles

Very pronounced fascicular twitchings were observed in the atrophied muscles especially in the I interosseous muscle Appreciation of light touch (wisp of cotton wood) and superficial pain (pinprick) was normal The V finger and the ulnar half of the IV finger felt dry suggesting slight hypohidrosis but the ninhydrin – sweat test was negative

The deep tendon and periosteal reflexes of the upper limb were normal The groove of the ulnar nerve was normal apart from a skin scar after a boil The abdominal skin reflexes were present Patellar tendon reflexes were present and symmetric The ankle jerk on the right side was more brisk than on the left The plantar reflex on the right side was atypical and periodically positive There was no paresis of the muscles of the lower limbs but 10 cm over the patella the right thigh was 1 5 cm smaller in circumference than the left

ELECTROMYOGRAPHY AND NERVE CONDUCTION VELOCITY

Electromyographic examination was performed The muscles examined were the first dorsal interosseous muscle and the abductor muscle to the fifth finger on both hands On the left side the electromyographic pattern was normal On the right side there was a neurogenic affection with moderate loss of motor units denervation potentials and fasciculation The mean duration of the potentials was within normal limits

Conclusion neurogenic affection on right side Nerve conduction velocity in both ulnar nervus measured from the region proximal to the sulcus nervi ulnaris to the wrist was normal (right nervus ulnaris 53 m/sec left nervus ulnaris 58 m/sec) (sign H J Hansen)

Muscle biopsy The biopsy was taken from the right abductor digiti quinti muscle The muscle had preserved longitudinal and transvers fiber bands In some areas there were fibres of normal diameter In other areas there was uniform atrophy of the fibers The nuclei were pressed together some of them were pyknotic and in a row The con nective tissue was normal The amount of fat was normal There was no sign of infection Microscopical diagnosis Neurogenic atrophy (sign Edith Reske Nielsen) X rays studies of the cervical spine did not reveal any abnormality

SIGNS AND SYMPTOMS

The symptoms and signs in the 20 cases from the literature (1 2) and in our own case may be briefly summarized as follows

Muscular atrophy The atrophy is unilateral and confined to the hand and part of the forearm The brachioradial muscle had preserved its volume so that the forearm seemed to be more slender in the mid portion Fascicular twitchings of the atrophied muscles were observed The atrophy progressed for some years and then stopped Tremorlike movements of the fingers were noted especially when working in the cold with small tools Motor weakness was always present and often one of the first symptoms especially when closing and spreading the fingers Some patients found it difficult to work with the affected hand especially in cold whether

Reflexes The deep tendon reflexes of the upper limb were usually symmetric Abdominal skin reflexes were normal In our patient there was a brisk ankle reflex on the affected side as in 2 cases of Hirayama and co workers They did not find positive Babinski reflex on the af fected side In our case there was an atypical plantar reflex on the affected side

A sensory disturbance was noted in a few patients hypesthesia in the affected hand but not in our case In our case there was slight hy pohidrosis of the V and half of the IV finger on the affected side Hypohidrosis was noted once (case 8) by *Hirayama* and co workers (2)

DIAGNOSTIC PROBLEMS

The diagnostic problems in our case were several We first thought the disease to be early acute anterior poliomyelitis There had not been any spell of fever no polio epidemic or polio in the patient s relatives

before onset of the disease The stationary course together with the localized atrophy with unique distribution and the characteristic age of onset enabled differentiation from the spinal progressive muscular atrophy

The slow progress the cessation of the disease together with the age at onset argue against amyotrophic lateral sclerosis The possibility of syringomyelia of the cervical cord was ruled out by the lack of sensory impairment Cervical spondylosis and cervical rib were not seen Hæmatomyelia multiple sclerosis and various kinds of inflammatory myelitis were differentiated by mode of onset and course

Carpal tunnel syndrom was easy to exclude as were other peripheral nerve injuries Atrophy in these disorders shows a different distribution and is accompanied by sensory disturbances

The so called parietal atrophy described more than a century ago (3) may also be considered This supranuclear lesion may lead to atrophy of the contralateral half of the body, or part of it However there is no phenomena of denervation or fasciculation Welander s disease can be ruled out by the age of onset Myopathies such as progressive muscular dystrophy and myositis are easily excluded The clinical course the muscle biopsy and the electromyographic findings did not sustain the diagnosis

The nature of the lesion and the cause of the disease are still unknown Juvenile onset, stationary course and male sex preponderance are characteristic No autopsy data are available The final diagnosis should await complete pathologic studies

SUMMARY

One case of juvenile muscular atrophy of unilateral upper extremity is described for the first time in Scandinavian literature The case is discussed together with 20 cases found earlier in Japan The disease is not inherited and predominantly males are affected Juvenile onset localized unilateral muscular atrophy especially of the arm and non progressive course in the stage are cardinal features of this disorder Electromyography demonstrates neurogenic affection and normal nerve conduction velocity in motor nerves Muscle biopsy shows the picture of neurogenic atrophy The disorder is distinctly different from any hitherto known entities of muscular atrophy As yet no pathologic studies have been reported

RESUME

Il est décrit pour la première fois dans la littérature scandinave un cas d'atrophie musculaire juvénile unilatérale de l'extrémité supérieure. Il est discuté de ce cas rapproché de 20 autres trouvés antérieurement au Japon. La maladie n'est pas héréditaire et elle atteint principalement le sexe mâle. Attaque juvénile, atrophie musculaire localisée notamment dans le bras d'un côté et n'ayant pas une évolution progressive dans le dernier stade sont les éléments cardinaux de ce trouble. L'électromyographie montre une affection neurogène et une vélocité de conduction normale des nerfs moteurs. Une biopsie du muscle donne le tableau d'une atrophie neurogène. Ce trouble est nettement différent de toute autre atrophie musculaire décrite jusqu'ici. Il n'a pas encore été effectué d'études pathologiques.

ZUSAMMENFASSUNG

Ein Fall von juveniler Muskelatrophie der oberen Gliedmasse einer Seite wird zum ersten Male in der skandinavischen Litteratur beschrieben. Der Fall wird zusammen mit 20 Fällen die früher in Japan gefunden wurden besprochen. Die Krankheit wird nicht vererbt und männliche Personen werden vorzugsweise ergriffen. Beginn in der Jugend, örtliche Muskelatrophie besonders im Arm einer Seite und nicht fortschreitender Verlauf im Spätstadium sind die Hauptzüge dieser Krankheit. Elektromyographie zeight eine neurogene Affektion und normale Nervenleitungsgeschwindigkeit in motorischen Nerven auf. Muskelbiopsie gibt das Bild einer neurogenen Atrophie. Die Krankheit unterscheidet sich deutlich von allen bisher beschriebenen Krankheiten muskulärer Atrophie. Bis jetzt sind noch keine pathologischen Studien vorgenommen worden.

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TUMOUR OF THE ULNAR NERVE

By

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Several papers have been written about paralysis of the ulnar nerve caused by mechanical pressure 1952 *Seddon* (6) gave a list including 4 cases caused by a ganglion and one case probably caused by a Dupuytren contracture

Brooks (1) gave a review of thirteen cases in which a ganglion in most cases coming from the neighbouring joint produced compression symptoms In 4 cases Brooks found a ganglion on the ulnar side of the elbow In 4 other cases he found ulnar affection from a typical ganglion compressing the ulnar nerve near the wrist or proximal in the palm In none of these cases was the ganglion found inside the nerve

A solitary tumour inside the deep branch of the ulnar nerve has been reported by *Jenkins* (2) The tumour was located inside the deep branch of the ulnar nerve with the nerve bundles spreading out over the surface of the tumour

In all together 7 Schwannomas of large nerve trunks *Money* (4) found pain in 5 cases the pain was of a sharp shooting character referring to the distribution of the affected nerve Paraesthesias were frequently noted *Money* (4) found no cases of Schwannoma with motor disturbance Peripheral nerve tumours are rare From 1910–1948 360 672 patients were admitted to the Royal Alfred Hospital Sydney and only 146 were found to have peripheral nerve tumours Carefully dissection of the nerve bundless away from the tumour was recommended by *Jenkins* (2) In malignancy the nerve trunk must be fully exposed above and below the tumour and no attempt made to save the nerve (*Money* (4))



Figure 1 The well circumscribed tumour localized inside the ulnar nerve the nerve bundles spread out over and around the tumour (Onion like appearance)
Figure 2 The neural sheath was incised the nerve bundles retracted gently with hooks and the tumour could be removed

CASE REPORT

A thirty nine year old housewife came to the out patient clinic in November 1966 (case record no 131 615) She complained of a lump situated above her left wrist on the volar aspect of the lower part of her left forearm She had been aware of the lump for some years and it had grown especially the last few months The lump was tender to direct trauma The last couple of years there had been some paraesthesia to the fifth and the ulnar half of the fourth left finger The patient had not noticed any weakness of the fingers Except for some left knee trouble 3 years previously the patient had been healthy

We found the patient to be healthy except for a plum sized tender tumour situated 6 cm above the left wrist over the ulnar part of the volar side of the forearm. The tumour was freely moveable and not adherent to the skin

By compression of the tumour the patient complained of numbness of the fourth and fifth fingers We did not find any other tumour localized to the subcutaneous tissue The pre operative diagnosis was a ganglion developing from the tendon sheaths

The patient was scheduled for operation on 9th December 1966 As the patient had complained of paraesthesia the operation was performed under general anaesthesia Before the operation the blood vessels in the arm were emptied At the operation we found a well circumscript tumour localized inside the ulnar nerve (Figure 1) The tumour was double with a narrow 1 5 cm long connection The nerve bundles were spread out over and around the tumour and gave it an onion like appearance The neutral sheath was incised by a knife With two hooks it was possible to split the sheath along the whole length of the tumour and with the hooks it was possible to retract the nerve bundles and the tumour could be easily removed (Figure 2) A narrow stalk located at the distal end of the tumour was cut through. After the operation the nerve bundles were undamaged No attempt was made to suture the nerve sheath. Two weeks after the operation the skin sutures were removed the patient still had some paraesthesia but less than before the operation There was no ulnar motor impairment no objectively

sensory disturbance Microscopically the tumour was built up of fine thread like tissue woven together in bundles In some places there was a plexiform structure The cells which were elongated and spindle shaped were arranged like a palisade No sign of malignancy Microscopical Diagnosis Neurinoma (*Sign Tage Lund*)

DISCUSSION

Several authors have tried to explain the origin of tumours in the peripheral nerves (1 2 4 5) Our case was a typical tumour developing from the sheath cells of Schwann There are two views on the origin of tumours of the nerve sheath *Stout* (7) believed that the tumours are derived from the sheaths of Schwann

The opposite view that these tumours arise from connective tissue is assumed by *Mallery* (3) and *Penfield* (5) In 3 cases *Jenkins* (2) found evidence suggesting that the tumours develop from the Schwann cells of the nerve sheaths and they should therefore be called neuri lemmonas

The tumours of the peripheral nerve are classified by *Jenkins* (2) as follows 1) False neuroma 2) Neurofibroma 3) Neurilemmona (Schwannomapalisade neuroma) 4) Neurofibrosarcoma

In a neurofibroma the neurofibrils extend through the tumour but in the Schwannoma the neurofibrils are split and run outside and around the tumour A Schwannoma often undergoes cystic degener ation A Schwannoma is nearly always solitary *Jenkins* (2) found that the lesion is benign *Wardle* (8) is of the opinion that the neurilem mona is of malignant nature He presented 5 four with a malignant picture with local recurrence and even one case with metastases from the sciatic nerve to the peritoneum Two cases of malignant Schwan noma reported by *Money* (4) occurred in the sheath of the sciatic and posterior tibial nerves respectively

SUMMARY

A case of A Schwannoma located in the left ulnar nerve at the wrist joint is reported The operative technique and the microscopical appearance are described The need for a careful case history and oper ation under general anaesthesia in a bloodless field is stressed

RESUME

Un cas de neurinome localise dans le nerf cubital de l articulation du poignet est rafforte La technique operatoire et les decouvertes micro-

scopiques sont decrites La necessite d une observation minutieuse du cas et d une operation sous anesthesie complete dans un champ vide de sang sont soulignes

ZUSAMMENFASSUNG

Ein Fall von Schwannom das im n ulnaris am Handgelenk gelegen war wird beschrieben Die operative Technik und das mikroskopische Bild wird beschrieben Die Notwendigkeit einer sorgfältigen Kranken geschichte und einer Operation bei voller Betäubung im blutlosen Feld wird hervorgehoben

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THROMBOSIS OF THE ULNAR ARTERY

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INTRODUCTION

Thrombosis or aneurysms in the arteries of the hand are not often mentioned in the literature and are perhaps seldom diagnosed It seems that until the publication of an article by *Kleinert & Volianitis* in 1965 only about 100 cases had been published (*Butsch & Janes* 1963, *Kleinert & Volianitis* 1965) The disease was first described in the late 18th century by *Guettani* (ref *Smith* 1962) but apparently attracted little attention In Scandinavia *v Rosen* published a case as early as 1934 *Leriche et al* in 1937 mentioned the disease in their work on arterial resections in the treatment of peripheral vasospasm For the past 20 to 30 years several reports of single cases have appeared some of aneurysms (*Middleton* 1933 *Smith* 1962 *Spittel* 1958 *Trevaskis et al* 1964 *Zuckerman & Proctor* 1946) and some of thrombosis (*Butsch & Janes* 1963 *Costigan et al* 1959 *Kleinert & Volianitis* 1965 *Spittel* 1958) These cases were predominantly in the ulnar artery at the level of the carpal bones

ANATOMY

The arcus volaris profundus receives its main supply from the radial artery while the arcus volaris superficialis gets its main supply from the ulnar artery Before ending in the superficial arcus the ulnar artery sends its ramus profundus to the arcus volaris profundus The ulnar artery passes deep to the short palmar muscle but superficially to the

We are greatly indebted to Dr *P Taarnhoj* Head of the Neurosurgical Department, County Hospital Glostrup and Dr *H Eltorm* MD Head of the Radiological Department County Hospital Glostrup for kindly placing their records and roentgenograms at our disposal

ligamentum carpi transversum Here it is situated just radial to the superficial branch of the ulnar nerve which is predominantly a sensory nerve Laterally it runs close to the pisiform bone and to the hamulus of hamatum Since this location is close to the strong ligaments and bony structures it might have a bearing on the aetiology

AETIOLOGY

The reason why thrombi and aneurysms form in this part of the ulnar artery is presumedly because the artery in this area is especially exposed to trauma It may be a question of repeated minor trauma as in monotonous work with consequent pressure of this segment of the ulnar artery against the deeper structures (*e g* working with pneumatic tools gear shifts etc) Or it may be a question of a more acute heavy trauma Such trauma is described in many of the published cases (*Butsch & Janes* 1963 *Costigan et al* 1959 *Jackson* 1954 *Kleinert & Volianitis* 1965 *Middleton* 1933 *v Rosen* 1934 *Smith* 1962 *Trevaskis et al* 1964 *Zuckerman & Proctor* 1946) Since such trauma is very common it seems strange that the disease does not occur more often The explanation might be that the relationship to trauma is not so precise or that the disease is more common than supposed and that it is often misdiagnosed

PATHOGENESIS

The formation of thrombi is presumably due to lesions of the intima and the formation of aneurysms seems to occur mainly through lesions of the tunica media (*v Rosen* 1934) Aneurysms might also be congenital but in fact most aneurysms seem to be of true acquired type and in some cases they are thrombosed

SYMPTOMATOLOGY

The symptoms may vary considerably The patient will often complain that a tender tense tumour has developed in the hypothenar region a sign which usually appears early in the disease Besides there are often marked episodes of vasospasm The patient will exhibit Raynaud s phenomenon and complain of pale and dead fingers especially when working or exposed to the cold The pallor might be accompanied by aching pain a sensation of burning and cyanosis In severe cases ulceration or gangrene may develop Neurological symptoms such as par

aesthesia and hypaesthesia in the sensory area of the ulnar nerve occurs perhaps because of the close anatomical relationship between the diseased artery and the superficial branch of the ulnar nerve which may be compressed or irritated by aseptic inflammatory reactions around the thrombosed artery

DIAGNOSIS

The diagnosis is made from the history the subjective complaints mentioned above and a positive Allen test This test is nearly always positive when the ulnar artery is thrombosed If there is a non thrombosed aneurysm a swelling can be seen which disappears when the artery is compressed above the site In such cases a bruit is often heard over the swelling

ALLEN TEST

This test is performed by compressing the radial artery at the wrist while the patient forcibly opens and closes the hand a few times Normally a slight transitory ischaemia will be seen which disappears quickly when the hand is kept still and compression maintained When the ulnar artery is not functioning due to thrombosis the pallor will persist for a long time during continued compression of the radial artery and marked ischaemic pallor will be seen In such cases the test is said to be positive During this final part of the examination the fingers should not be hyperextended since such hyperextension will result in a false positive reaction

Positive results of the Allen test will be sufficient to make the diagnosis Further evidence can be obtained by brachial arteriography Many authors emphasize that this is hardly necessary and a few authors warn against this method because of the possibility of provoking vasospasm which might lead to an exacerbation of the disease One participant in a discussion at the Mayo Clinic (*J W Lord* quoted by *Butsch & Janes* 1963) mentioned a case where gangrene developed after arteriography

TREATMENT

The treatment of this disease varies It may be by conservative methods using vasodilators anti coagulants or perhaps even steroid drugs and cessation of smoking In addition conservative surgical treatment such as sympathectomy performed after a good response to injection of the

stellate ganglion has been shown to be effective but not uniformly so because sympathectomy will eliminate vasoconstriction and does not stimulate the vasodilating apparatus (*Bulsch & Janes* 1963)

Finally there is radical surgical treatment consisting of resection of the injured part of the ulnar artery followed by ligation of the ends The ultimate objective is (*Leriche* 1937) to remove the part of a vessel which is thought to provoke the vasospasm and to encourage the formation of collaterals This treatment has been used effectively in the majority of reported cases Furthermore surgical treatment may be conservative with multiple arteriotomies and endarterectomies or resection of the thrombosed area and end to-end anastomosis of the vessel This latter method has been successfully used by *Kleinert & Volianitis* (1965) in 9 cases The authors did not follow up the patients arteriographically but reported a good result in a case where the Allen test again had proved positive

It is still debatable whether this treatment is superior to resection and ligation

CASE REPORTS

The disease is more common than what is indicated by the number of single cases reported During the period of about one year we observed 6 cases which are described below

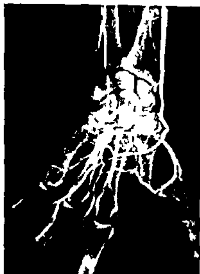
Case 1 A 49 year old labourer whose mother had a tendency to vasospasm in the fingers In 1959 the second right finger was amputated after an accident On admission to hospital on 6th December 196 he complained of prickling pain of about one year s duration in the middle and right fingers of his right hand The attacks occurred 1 to 3 times a day and lasted from 5 minutes to 2 hours During the attacks the fingers were pale and the spasms were followed by paraesthesia and pain Cold and hard work provoked the attacks No symptoms were seen in the other hand or in the lower extremities At the onset of symptoms the patient noticed swelling of the hand and lower forearm Vasodilators were tried but without success In his work he had been using pneumatic tools Before he was admitted to hospital he had been incapable of working for about 9 months

Physical findings Slight arteriosclerotic changes at ophthalmoscopy No evidence of costoclavicular arterial compression Slight cyanosis in the middle and ring fingers of the right hand No trophic changes Allen test was positive on the right side and negative on the left

The diagnosis of thrombosis of the ulnar artery was based on the criteria mentioned above The patient had been treated with infiltration of the stellate ganglion with a good but transitory response Transferred to the neurosurgical department County Hospital Glostrup he was examined with brachial arteriography which showed evidence of thrombosis at the level of the carpal bones (Figure 1)

A right thoracic sympathectomy of the the 2 3 and 4 ganglion was performed with an immediate and good relief of the symptoms After the operation some

Figure 1 Brachial arteriogram showing occlusion of the ulnar artery at the carpus (Case 1)



neuralgic pains developed due probably to a slight contusion of the brachial plexus during operation Four months after operation when the patient was reexamined the neuralgic pains had subsided and the vasospastic symptoms had disappeared but the Allen test was still positive The prognosis is thought to be good If the symptoms recur regional resection of the ulnar artery will be offered

Case 2 A 66 year old man who is a small holder Six months before admission to hospital he was operated on because of benign pyloric stenosis Three months before presentation without preceding trauma he noticed an increasing somewhat tender swelling ot the base of the left hypothenar region The swelling persisted for about 2 months No signs of vasospasm

Physical signs On Februar 15 1966 before admission to hospital a slight tender lump of 2 by 1 cm in size was found at the base of the left hypothenar region It was deep seated not movable and not circumscribed The diagnosis was thought to be a deep seated ganglion When admitted to hospital on 1st March 1966 the lump and tenderness had decreased He was operated upon three days later using a bloodless field It was then found that the ulnar artery was thrombosed and a small embolus proximal to the thrombosed area was noticed The pathological changes were spread only in the area of the ramus superficialis The artery was normal where the profound branch was given off A slight inflammatory reaction oedema discoloration of the fat and a little serous fluid was found around the vessel The superficial branch of the ulnar nerve was intact Distal to the thrombosed area the artery was likewise normal (Figure 2) A small arteriotomy was done The degenerated intima was removed together with the embolus After suture of the incision with atraumatic silk no 00000 the blood flow was excellent through the artery so that regional resection was not performed In the post operative phase the patient had a little stiffness of the fingers which improved steadily with exercise and physiotherapy and a slight paraesthesia in the ulnar area which subsided spon



Figure 9 Operative findings in Case 2 showing occlusion of the ramus superficialis of the ulnar artery The thrombosed area is seen between the slings ulnarly the superficial branch of the ulnar nerve is exposed

taneously These symptoms were not present before the operation The Allen test had not been performed before operation because vasospasm had not been present and the disease had been misdiagnosed as a gan lion One month later the positive Allen test showed evidence that the artery had thrombosed again If vasospastic symptoms recur we shall consider reoperation and resection of the diseased part of the artery This patient has no history of heavy or repeated minor trauma. He is a farmer however accustomed to heavy work and he is lefthanded

Case 3 A 26 years old man of low intelligence On 20th May 1966 he sustained a heavy blow against the left hand on the volar side of the wrist. X ray revealed no fracture Swelling and ecchymosis were present and the patient was treated by his general practitioner for sprain of the wrist One week later there was some stiffness of the fingers together with tingling and hypaesthesia on the volar aspects of the three ulnar fingers The patient was treated with ultrasonic waves and finger exercises The condition of his fingers varied during this period He complained of coldness of the fingers which were from time to time cyanotic but actual vasospastic attacks were difficult to trace because of his poor intellect. Pulsation was felt in the radial artery at the wrist but not in the ulnar artery 5 months after the trauma further exacerbation of the symptoms with attacks of cyanosis pains and swelling occurred Slight hyperhidrosis and some atrophy of the skin were present, no radiological signs of Sudeck s atrophy were seen The patient was again admitted to hospital and 6 injections of the stellate ganglion were given. Percutaneous brachial arteriography showed filling of the arcus volaris profundus from the radial artery but no filling in the arcus volaris superficialis Nevertheless, there was filling of the very ulnar part of the superficial branch of the ulnar artery Injections of the stellate ganglion were continued and anti-coagulating therapy was started simultaneously After 2 months, there was improvement and at the last follow up there were no signs of Sudeck s atrophy

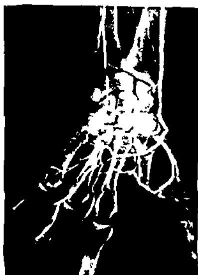


Figure 1 Brachial arteriogram showing occlusion of the ulnar artery at the carpus (Case 1)

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Figure 2 Operative findings in Case 2 showing occlusion of the ramus superficialis of the ulnar artery The thrombosed area is seen between the slings ulnarly the superficial branch of the ulnar nerve is exposed

taneously These symptoms were not present before the operation The Allen test had not been performed before operation because vasospasm had not been present and the disease had been misdiagnosed as a ganglion One month later the positive Allen test showed evidence that the artery had thrombosed again If vasospastic symptoms recur we shall consider reoperation and resection of the diseased part of the artery This patient has no history of heavy or repeated minor trauma He is a farmer however accustomed to heavy work and he is lefthanded

Case 3 A 26 years old man of low intelligence On 20th May 1966 he sustained a heavy blow against the left hand on the volar side of the wrist. X ray revealed no fracture Swelling and ecchymosis were present and the patient was treated by his general practitioner for sprain of the wrist One week later there was some stiffness of the fingers together with tingling and hypaesthesia on the volar aspects of the three ulnar fingers The patient was treated with ultrasonic waves and finger exercises The condition of his fingers varied during this period. He complained of coldness of the fingers which were from time to time cyanotic but actual vasospastic attacks were difficult to trace because of his poor intellect. Pulsation was felt in the radial artery at the wrist but not in the ulnar artery 5 months after the trauma further exacerbation of the symptoms with attacks of cyanosis pains and swelling occurred Slight hyperhidrosis and some atrophy of the skin were present no radiological signs of Sudeck s atrophy were seen The patient was again admitted to hospital and 6 injections of the stellate ganglion were given Percutaneous brachial arteriography showed filling of the arcus volaris profundus from the radial artery but no filling in the arcus volaris superficialis Nevertheless there was filling of the very ulnar part of the superficial branch of the ulnar artery Injections of the stellate ganglion were continued and anti-coagulating therapy was started simultaneously After 2 months there was improvement and at the last follow up there were no signs of Sudeck s atrophy

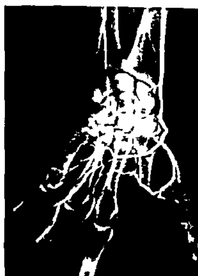


Figure 1 Brachial arteriogram showing occlusion of the ulnar artery at the carpus (Case 1)

neuralgic pains developed due probably to a slight contusion of the brachial plexus during operation Four months after operation when the patient was reexamined, the neuralgic pains had subsided and the vasospastic symptoms had disappeared, but the Allen test was still positive The prognosis is thought to be good If the symptoms recur regional resection of the ulnar artery will be offered.

Case 2 A 66 year old man who is a small holder Six months before admission to hospital he was operated on because of benign pyloric stenosis Three months before presentation without preceding trauma he noticed an increasing somewhat tender swelling ot the base of the left hypothenar region The swelling persisted for about 2 months No signs of vasospasm

Physical signs On Februar 15 1966 before admission to hospital a slight tender lump of 2 by 1 cm in size was found at the base of the left hypothenar region It was deep seated not movable and not circumscribed The diagnosis was thought to be a deep seated ganglion When admitted to hospital on 1st March 1966 the lump and tenderness had decreased He was operated upon three days later using a bloodless field. It was then found that the ulnar artery was thrombosed and a small embolus proximal to the thrombosed area was noticed The pathological changes were spread only in the area of the ramus superficialis The artery was normal where the profound branch was given off A slight inflammatory reaction oedema, discoloration of the fat and a little serous fluid was found around the vessel The superficial branch of the ulnar nerve was intact. Distal to the thrombosed area the artery was likewise normal (Figure 2) A small arteriotomy was done The degenerated intima was removed together with the embolus After suture of the incision with atraumatic silk no 00000 the blood flow was excellent through the artery so that regional resection was not performed In the post operative phase the patient had a little stiffness of the fingers which improved steadily with exercise and physiotherapy and a slight paraesthesia in the ulnar area which subsided spon

RESUME

Description d une thrombose de l artere cubitale Comme la formation d un anevrisme dans cette artere la maladie semble souvent avoir une etiologie traumatique Il est discute de la base anatomique de l etiologie et de la pathogenese 6 cas sont rapportés Le diagnostic a ete verifié par l operation l arteriographie et en particulier par un test Allen posi tif Il est souligné que la maladie est plus frequente qu on ne le suppose généralement et qu elle est souvent mal diagnostiquee

ZUSAMMENFASSUNG

Eine Beschreibung der Thrombose der a ulnaris wird gegeben Die Er krankung scheint ebenso wie die Bildung eines Aneurismas in dieser Arterie oft auf traumatischer Grundlage zu entstehen Die anatomische Basis die Athiologie und die Pathogenese werden besprochen 6 Falle werden berichtet Die Diagnose wurde durch die Operation die Arterio graphie und besonders durch eine positive Allen Probe bestatigt

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OSTEOARTHRITIS OF THE TRAPEZIO SCAPHOID JOINT

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Received 9 xi 67

Degenerative changes in the carpal joints are common and often the cause of disabling pain which seriously interferes with function Of the midcarpal joints those into which the greater multangular bone enters appear to be most commonly affected Much attention has been given to the carpo metacarpal (CMC) joint of the thumb one of the most frequent localizations of primary osteoarthritis (*Lasserre et al* 1949 *Brailsford* 1953, *Aune* 1955 and others) The purpose of this article is to emphasize a condition which as far as we can find from the literature has attracted no attention This concerns the *isolated* osteoarthritis of the trapezio scaphoid (T S) joint of the wrist (Figures 1 and 2) Our interest was aroused by finding this particular localization of joint degeneration in patients complaining of radial volar swelling at wrist level clinically with appearance of a ganglion It was found by contrast injection into the carpal joint that as a rule communication existed between the diseased T S joint and the space surrounding the flexor carpi radialis (FCR) tendon (Figure 3)

Anatomically the trapezium is an intermediate bone placed in a vulnerable position between the first metacarpal and the scaphoid Adjacent to the volar aspect of the bone lies the tendon of the FCR which inserts at the base of the second metacarpal (Figure 4)

It is well known to everyone who deals with hand surgery that radial volar ganglia differ in character from dorsal wrist ganglia They usually have thin walls they may be polycystic and are often intimately connected with the FCR tendon and disappear distally into the carpus along the tendon They may contain the same type of jelly or fluid as dorsal ganglia



Figure 1 Local osteoarthritis between the trapezium and the scahphoid
a) radial flexion of the wrist
b) ulnar flexion of the wirst



Figure 2 Advanced osteoarthritis of the trapezio scaphoid joint



Figure 3 a) Lateral view Contrast leaking out around the tendon of flexor carpi radialis
b) Frontal view same case



Figure 4 a) Volar flexion Contrast leaking up along the flexor carpi radialis tendon to mid level of fore arm
b) Dorsal flexion same case

CLINICAL MATERIAL

Since our attention was directed to the possible connection between volar "ganglion and osteoarthritis in the T S joint we have radiographically examined patients with radial volar swellings at the wrist

In order to get an idea of the incidence of isolated osteoarhritis in the T–S joint among patients with this condition and above 30 years of age a follow up study was made of the cases seen in our department during the last 15 years

Those who revealed degenerative changes in the T-S joint underwent arthrography whereby the contrast medium usually was injected into the carpal joint from the dorsal aspect of the wrist. Some patients with radial volar swelling but without radiological carpal changes were also examined by arthrography representing the controls.

Table 1. Cases with osteoarthritis in T-S joint

			Initial sympt.		Osteo arthritis				Arthrography		
Case No	Age	Sex	Volar tumor	Pain	CMC	T-S	Volar tumor at time of arthrography	Operated	Contrast around FCR	Contrast in gangl	Comments
1	66	F	+	+	(+)	+	+			+	
2	68	F	+		+	+		+	+		
3	40	F		+		+			+		
4	64	F	+	+		+	+		+		
5	59	F	+	+		+		+	+		
6	66	F	+	+	+	+		+	+		
7	79	F	+	+		+		+	+		
8	63	F	+	+		+	+		+		
9	63	F	+	+		+	+		+		
10	70	F		+		+			+		
11	77	F	+			+	+			+	
12	52	F	+	+		+	+		+		
13	63	F	+	+		+	+		+		
14	55	F	+	+		+		+			
15	55	F	+	+		+	+		?		No arthrography
15	60	F	13	13	3	15	8	5	11	2	

RESULTS

A total of 48 cases were examined. Isolated osteoarthritis of the T-S joint was found in 12 cases while 3 cases had additional changes in the CMC joint of the thumb. Isolated changes in the first CMC joint were found in 5 cases while the rest of the 28 cases had normal radiological findings (Table 1).

The cases with affection of the T-S joint are listed in Table 1. All patients are female and middle aged. Most of them complained of pain and local swelling at wrist level. Contrast filling of the peritendinous space of FCR was found in 11 cases. The contrast followed the tendon

in a proximal direction ultimately visualizing the clinically found wrist swelling In some cases the contrast even followed the tendon to the mid level of the forearm In 2 cases a ganglion was filled without contrast leaking out around the tendon and in 1 case finally arthrography was not done Thus in one case only communication could not be demonstrated between the diseased T S joint and the peritendinous space or the volar swelling respectively Six cases with radial volar wrist swelling but normal radiological findings were also examined with contrast injection into the carpus In 5 of these normal anatomy was found while in the sixth case contrast was found around the FRC-tendon It should be mentioned however that this patient had been *operated several times for recurring ganglion at this site*

DISCUSSION

The numerous theories about ganglia found in the literature testify to the lack of agreement concerning the aetiology of this condition It is reasonable to assume that no single explanation can be given Whatever the cause may be however it seems probable from their proximity to joints that ganglia bear some relationship to synovial fluid From the findings in the present investigation it seems quite clear that a great number of so called radial volar wrist ganglia have a definite relationship to localized degenerative changes in the T S joint

The frequency of primary osteoarthritis of the CMC joint of the *thumb has been pointed out by most authors dealing with this subject* According to the present observations isolated changes in the T S joint are not uncommon and it is therefore curious that this condition seems to have been overlooked The clinical aspect of the condition has an interesting difference from osteoarthritis in the CMC joint in that it frequently gives rise to the above described volar wrist swelling

Considering the nature of this progressive degenerative joint disease it is not difficult to conceive that a rupture of the fibres of the T S joint capsule may easily be produced This would allow synovial fluid to escape from the joint and by the movements of the wrist to be forced into the periarticular tissue At this point the FRC tendon comes in close contact with the joint capsule on its way to insertion on the second metacarpal The synovial fluid may follow the tendon proximally and finally *become of clinical significance as a ganglionlike soft tissue* tumor at wrist level

At least in middle aged and older females before the surgeon operates

for volar radial wrist ganglia it is recommended that he looks for radiological changes in the T-S joint When changes are obvious arthrograms of this joint should be made

SUMMARY

Localized degenerative changes in the trapezio scaphoid joint have been observed in middle aged females who complain of wrist pain and have a volar radial swelling at wrist level Arthrographic studies have revealed communication between this diseased joint and the peritendinous space of the flexor carpi radialis clinically often appearing as a ganglionlike swelling The pathophysiology is discussed

RESUME

Des modifications degeneratives localisees dans l articulation trapezo scaphoidienne ont ete observees chez des femmes d un certain age qui se plaignent de douleurs dans le poignet et qui ont une enflure palmaire radiale au niveau du poignet Des etudes arthrographiques ont revele un rapport entre cette maladie articulaire et l espace peritendineux du flechisseur carpi radial apparaissant souvent en clinique sous la forme d une enflure ganglionnaire Il est discute de la pathophysiologie de la maladie

ZUSAMMENFASSUNG

Ortliche degenerative Veranderungen im multangulumnaviculare Gelenk wurden bei Frauen im mittleren Alter die uber Handgelenks schmerzen klagen und eine volare radiale Schwellung in der Hohe des Handgelenkes haben beobachtet Arthrographische Untersuchungen haben eine Verbindung zwischen diese erkrankten Gelenke und dem peritendinosen Raum des Flexor carpi radialis gezeigt was sich klinisch oft in einer ganglionartigen Schwellung aussert Die Pathophysiologie wird besprochen

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KIENBOECK'S DISEASE TREATED WITH OSTEOTOMY TO LENGTHEN ULNA

By

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Received 7 iii 67

The first report of chronic progressive osteochondrosis of the carpal lunate bone was reported by *Kienboeck* in 1910 since when various hypotheses have been put forward to explain the disease and several methods of treatment have been suggested *Kienboeck* s conception of the disease as primary necrosis because of a circulatory disorder with secondary fractures has long been refuted as have other theories such as Axhausen s which ascribes the necrosis to mycotic embolism According to the present consensus of opinion the cause of the condition is a primary compression fracture with interruption of some or all of the blood vessels reaching the lunate bone through its volar and dorsal surfaces This conception is supported by the work of *Stahl* (1947) He and others who have studied the physiology and mechanics of the wrist have shown that this bone is acted upon by the majority of local forces arising on movement of the hand and wrist and is therefore exposed to the risk of injury

Hultén (1928) stressed that the lunate bone faces the articular surface of the radius and the triangular disc which consist of much softer tissue A further anatomic feature of importance in the causation of the disease is according to *Hultén* shortness of the ulna relative to the radius so-called minus variation which places an abnormal strain and stress on the lunate bone Of 400 normal wrists *Hultén* found minus variation in 23 per cent no variation *i e* articular surface of radius and ulna at the same level—in 61 per cent and relative shortness of the radius relative to the ulna—minus variation in 16 per cent Of 23 patients with osteochondrosis of the lunate bone they found minus variation in 74 per cent no variation in 26 per cent and no plus

variants In a compilation of 338 cases from the literature *Persson* (1945) found minus variation in 60 per cent and no variation in 40 per cent and plus variation in none *Stahl* has shown that plus variation may sometimes occur although rarely Another argument for the fracture theory is that the disease occurs mostly in men and then as a rule in the hand used most *i e* generally the right one

TREATMENT (Table 1)

Table 1 Results obtained with different methods of treatment

	Excision of lunate bone	Lunate bone replaced by prosthesis	Immobilisation in plaster	Elongation ostetomies: Literature cases	Elongation ostetomies: Personal cases
Number of cases	65	17	293	54	10
Average interval between op and review (years)	6	4½	10	6	13½
Arthrosis of the wrist (in % of total)	90–100	90–100	80–90	30	20
No significant symptoms (%)	54	53	31	91	100
Symptoms reducing function (%)	12	24	38	6	0
Disabling (%)	34	23	31	4	0

Conservative The commonest and oldest type of treatment consists of immobilisation in plaster In a compilation of literature cases *Persson* (1945) found this method to have produced a good result without any significant persistent symptoms in 49 improvement but symptoms in association with heavy work in 57 and poor results or complete loss of function of the wrist in 56 In *Stahl* s (1947) series of 142 patients all pain disappeared *in 31 71 had pain on movement of the wrist* and 13 were obliged to change their occupation but arthosis deformans of the radio-carpal joint was seen in as many as 94 of 104 examined Ståhl concluded that when the wrist was immobilised for less than 2 months the result was poor in every second patient but in only every sixth when the wrist was immobilised for a longer period

Excision of the lunate bone According to *Campbell et al* (1964)

Stahl (1947) and *Besutti* (1964) the end results of excision of the lunate bone are poor *Dornam* (1949) and *Gillespie* (1961) however reported good results the latter in 21 of 24 cases though they like other authors invariably observed progressive arthrosis and stiffness of the wrist The general consensus today is that excision of the lunate bone is a mutilating operation with serious secondary changes in the wrist and that it is therefore no longer justified

Replacement of lunate bone by an artificial substitute This operation was performed with success on 1 patient reported by *Danis* (1951) *Agerholm & Goodfellow* (1963) reported 15 cases where the lunate bone was replaced by an acrylic prosthesis 13 of the patients were satisfied with the result 8 were symptomfree and 7 had only mild symptoms but this operation too was invariably followed by progressive arthrosis of the wrist

Osteotomy for lengthening the ulna In view of Hultén s theory of the abnormal loading of the lunate bone especially if the ulna is short Persson described a method for lengthening the ulna distally the lunate bone is unloaded to promote healing with minimum secondary arthrosis of the wrist In 1945 Persson described his method and the results obtained in 19 patients operated upon and 5 years later he reported a further 14 cases in most of which the results were good *Desenfans* (1953) *Leitner* (1954) *Verbrugge & Verjans* (1963) and *Besutti* (1964) also reported cases treated successfully by this method

Judging from the literature then osteotomy produces satisfactory results more often than other methods available for the treatment of the condition

PRESENT SERIES (Table 2)

Nine patients with Kienboeck s disease which was bilateral in one of them were treated with osteotomy of the ulna *ad modum* Persson Three of the patients were below 20 five were between 20 and 30 and one was above 30 years One patient was left handed He and one patient who was right handed were operated upon on the left side the remaining 7 on the right side One of the patients was a woman the remaining 8 were men with heavy manual occupations Four had trauma in their histories Before the operation 4 of the wrists showed no variation and 6 showed minus variation There were no plus variants Seven wrists had been treated for 2-8 months previously with immobilisation but without success Only 1 of the wrists had produced symptoms for more

Table 2

											Sum
Sex	M	F	M	M	M	M		M	M	M	
Side	L	R	R	R	R	R	L	R	R	R	
Follow up period in years	18	19	19	19	19	17	5	14	4	1½	M = 13½
Tenderness on palpation	/	/	/	—	/	—	—	X	—	/	6
Intermittent pain	/	/	/	/	/	/	/	/	—	—	8
Heavy occupation	/	/	/	—	/	—	—	/	/	/	7
Wrist stronger than before operation	/	/	/	/	X	/	/	/	—	/	9
Dynamometer in % of contralateral hand	63	45	100	100	97	–	–	100	88	110	M = 79

M = Mean

than 1 year The interval between the operation and the present review was on the average 13½ years

OPERATION TECHNIQUE

The operation was usually performed under plexus or axillary blockade sometimes in a bloodless field An incision about 10 cm long was made along the subcutaneous border of the ulna down towards the styloid process of the ulna and the ulna was dissected and exposed subperiosteally To obtain stability after the osteotomy and a rough surface to promote healing the bone was cut obliquely with a chisel through a 10 cm premarked line along which a number of holes had been drilled to facilitate the chiselling and to prevent the bone from splitting The purpose was to secure a plus variation of 3–4 mm After the desired increase in length of the bone was calculated holes were drilled in the radioulnar direction in the distal and proximal fragments respectively the level between consecutive holes being equal to the distance the bone was to be lengthened (Figure 1) A piece of wire was threaded through the holes and with the aid of a wire twister desired lengthening could be easily obtained If the osteotomy is placed in the way illustrated in Figure 1 the distal fragment can be readily gripped with a single pronged hook and retracted with simultaneous radial deviation of the wrist to facilitate the lengthening still more According to *Desenfans Verbrugge* and *Verjans* the method has fallen into disrepute because of the difficulty in obtaining the desired elongation They therefore recommend step osteotomy and the use of a Duchene plate for fixation But with this procedure the osteotomy is still more unstable and the presence of the plate on subcutaneous bone retards healing of the skin a side effect that occurred also in the Verbrugge and Verjans series But if the above method is applied strictly according to instructions extension is readily obtained and good stability can be obtained by the use of 2 supplementary cerclages The rough chiselled and bored osteotomy prevents slipping and at the same time promotes healing

After the operation a dorsal plaster splint is applied from the metacarpo phalangeal joints to half way up the overarm with the elbow flexed 90 and the hand in midposition between pronation and supination After about 2 weeks the sutures are drawn and the splint is replaced by a circular plaster after which the patient may be treated at the out patient department for 8 weeks after the operation by which time the osteotomy has usually healed In the present material the bone

Table 2

Sex	M	F	M	M	M	M		M	M	M	Sum
Side	L	R	R	R	R	R	L	R	R	R	
Follow up period in years	18	19	19	19	19	17	[illegible]	14	4	1½	M = 13½
Tenderness on palpation	✓	✓	✓	—	✓	—	—	✓	—	✓	6
Intermittent pain	✓	✓	✓	✓	✓	✓	✓	✓	—	—	8
Heavy occupation	✓	✓	✓	—	✓	—	—	✓	✓	✓	7
Wrist stronger than before operation	✓	✓	✓	✓	✓	✓	✓	✓	—	✓	9
Dynamometer in % of contralateral hand	73	45	100	100	27	–	–	100	98	110	M = 79

M = Mean

(Table 3) On the other hand ulnar and radial deviation as well as pronation and supination were barely affected

Table 3 Impairment of mobility in degrees compared with range of motion of contralateral wrist

	0	5	10	15	20	25	30	Mean
Dorsal flexion	3	[illegible]	2	1	0	2	0	9
Volar flexion	2	1	4	0	1	1	1	11
Ulnar deviation	2	5	2	0	1	0	0	3
Radial Deviation	8	2						1
Pronation	3	6	1					4
Supination	9	1						1

Roentgenography showed that all the osteotomies had healed normally In 7 cases the structure of the lunate bone had improved (Table 4) with healing of the fragments and of the cysts (Figures 2–3) in 1 case the structure was unchanged and in 2 the structure had deteriorated with increase of the cysts in one with both increase of the cyst and with fragmentation in the other These changes had no appreciable effect on the function of the hand and the patients were still carrying on with their usual heavy manual occupation So were the 2 patients who had mild arthrosis of the radio carpal joints with marginal sclerosis and 1 patient with narrowing of the joint space between the naviculare and

Table 4 Cases arranged in same order as in Table 2

Increase in length of ulna	2–3 mm								\	—	Y	2
	4–5 mm	\	\	\	\	Y	\	Y		—		7
Increase in proximo distal dimension of lunate bone		0	+	+	+	+	+	+	0	0	0	6
Improvement of structure of lunate bone		+	0	+	+	+	+	+	—	—	+	7
Radio carpal arthrosis			\			Y						2
Arthrosis between navicular and trapezoideum				\								1



Figure 2. A wrist with Kienboeck's disease immediately before operation (left) and a review 18 years later (to right).



Figure 3. Lunate bone immediately before operation (left) and at review 17 years later (to right). Note the elongation of ulna.

the trapezoideum. Though not arthrotic, the naviculare and the trapezoideum showed sharp edges in 8 wrists and the triquetrum and hamatum in 2. These changes may perhaps be ascribed to the changes in the mechanics and loading of the wrist. Restitutio ad integrum was not observed in any of the cases. Neither could complete recovery be expected, for the fractures were not reduced and were thus left to heal in their compressed state. In 6 cases the proximo-distal dimension of the lunate bone had, however, increased in thickness, in 4 it was the same as before the operation and in none had it become shorter.

All of the patients were very satisfied with the result of the operation. Two who had, however, been obliged to take lighter work, still thought that they could use the hand unhindered. The remaining 7 had returned to their previous heavy work in the woods and on the land.

SUMMARY

Nine patients (10 wrists) with Kienboeck's disease treated with osteotomy for lengthening the ulna *ad modum* Persson are described. The patients were reviewed on the average $13\frac{1}{2}$ years after the operation. The clinical end results were very good and all the patients were satis

fied In none of the cases did roentgenography show such severe arthrosis of the radio-carpal joint as that seen after treatment with other methods

Judging from published reports and the cases described here osteotomy is the best available method in the treatment of the condition

RESUME

Neuf malades (10 poignets) souffrant de la maladie de Kienboeck on éte traites par osteotomie pour allonger le cubitus d après la methode Persson Il est donne une description de ces cas Les malades ont éte reexaminés au bout d une periode moyenne de 13 ans et demi apres l operation Les resultats finaux cliniques etaient excellents et tous les malades etaient satisfaits Dans aucun des cas la radiographie ne montra une arthrose grave de l articulation radio-carpale que l on rencontre souvent apres le traitment par d autres methodes

A en juger des rapports publiés et des cas decrits ici l osteotomie est la meilleure méthode de traitement a disposition dans ces circonstances

ZUSAMMENFASSUNG

Neun Patienten (10 Handgelenke) mit Kienboeck s Erkrankung die mittels Osteotomie zur Verlängerung der Ulna *ad modum* Persson behandelt wurden werden beschrieben Die Patienten wurden durchschnittlich 13½ Jahre nach der Operation untersucht Die klinischen Resultate waren sehr gut und alle Patienten waren zufrieden In keinen der Falle zeigte die Rontgenuntersuchung so schwere Arthrosen des Radio-carpalgelenkes als die welche man nach Behandlung mit anderen Methoden beobachtet

Gemass veroffentlichten Berichten und den hier beschriebenen Fallen ist die Osteotomie die am besten anwendbare Methode in der Behandlung dieses Zustandes

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FLEXOR TENDON GRAFTS

Results in 95 Cases

By

A Weilby

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After the technique of free tendon grafting has gradually become so firmly established that the operation is a routine procedure it has been introduced in several departments all over Denmark In this connection it is perhaps of interest to ascertain the results obtained in a department of general orthopaedic surgery by this operation considered by many hand surgeons a task which makes the utmost demands on the surgeon's skill

MATERIAL AND METHODS

The present analysis comprises the results of 95 free tendon graftings performed in the Orthopaedic Hospital Aarhus during the period 1949–1965 These operations done on a total of 90 patients are equally distributed on the digits of the right and left hand The distribution of the digits is shown in Table 1 The patients ranged in age between [illegible] and 6[illegible] years 31 patients were younger than 15 and 6 were older than 50 The age distribution is listed in Table 2 On the basis of the manner of injury the operated digits may be divided into 2 groups [illegible] digits with uncomplicated clean cuts and digits showing crush injuries and lacerations often with fractures articular and nerve damage Sequelae of previous tendon suture or tendon grafting must be assigned to the latter group

The tendon grafting was carried out in 18 cases because of injury to the flexor pollicis longus in the tendon sheath and in 76 cases because of injury to both flexor tendons within the fibrous tendon sheaths of the fingers (Bunnell's "no man's land") Only in one case was tendon grafting done because of an isolated injury to the flexor digitorum profundus preserving the flexor digitorum sublimis.

Preoperatively it was endeavoured to obtain a full passive mobility of the finger joints. Union of fractures was awaited, scar formations were corrected skin grafting was done and in some cases nerve repair [illegible]0 of the digits were operated upon within the first 4 months after the accident only 4 more than 1 year after

The operation was carried out in a bloodless field after disinfection by soap and water The approach was mid lateral in about half the operations dorsal to and in

the other half volar to the nerve vessel bundle In some cases this incision was combined with a transverse incision In the palm the incisions were applied parallel to the natural creases As a donor tendon we used the tendon of the extensor digitorum longus (pedis) in 62 cases that of the plantaris longus in 4 and that of the palmaris longus in 28 cases In one case it is not stated from where the donor tendon was taken When the tendon of the extensor digitorum longus pedis was used its distal end was fastened to the tendon of the extensor digitorum brevis pedis

Table 1 Distribution on the digits of the operations

	Thumb	2nd digit	3rd digit	4th digit	5th digit
Number of operations	18	20	30	13	14

Table 2 Age distribution of the patients

Age groups	0–9	10–19	20–29	30–39	40–49	50–59	60–69
Number of patients	18	33	18	8	7	4	2

The fixation of the tendon to the distal phalanx was done in 58 cases by suturing the tapered graft with knotted silk 0000 in a V shaped cut to the distal stump of the flexor digitorum profundus In 37 cases the tendon was fastened to a hole drilled into the distal phalanx using pull out wire Proximally the suture was performed as interlacing or fish mouth suture using silk 0000 (in a few cases wire) The suture line was covered with the lumbricalis muscle When suturing to the flexor pollicis longus the suture line was applied as far proximally as possible but not always in the muscle Prior to or during the operation 27 of the 81 injured nerves on the operated digits were repaired In 9 cases nerve grafting was done The suturing was done with silk 0000000 During the operation damaged pulleys were reconstructed Pressure dressing was applied with a plaster cast, and the tendon was kept non functioning for 3 weeks Pull out wires were removed at the end of 4 weeks and at the same time exercises were started In some cases showing contractures an elastic traction splint was used for a varying length of time

Follow up

Out of a total of 90 patients 72 were examined in their homes About the others relevant data were found in the case records 6 had gone abroad 4 had died of irrelevant causes one has undergone amputation one had a stiff useless finger and 6 were not seen for other reasons The follow up period was between 1 and 18 years except in 4 cases less than 1 year

The function of the tendon is reflected in the excursions of the distal phalanx If the extension defect of the distal phalanx is recorded as the sum total of the extension defects of the three joints and the flexion ability of the distal phalanx as the sum of the excursions in the three joints when the finger is flexed maximally

Table 3

Tendon grafts in the fingers 77 cases	Age at operation	Lesion of digital nerves	Extension defect in the distal phalanx	Mobility of the distal phalanx	Mobility in the MP joint	Mobility in the proximal IP joint	Mobility in the distal IP joint	Flexion defect in distal phalanx
Age 2–15 years	14	1	normal					
uncomplicated cases	11	0	10	270	100	105	65	0
(clean cut)	11	2	20	260	100	105	55	0
	15	1	25	235	110	100	25	10
	7	1	5	230	90	100	40	35
	4	0	0	220	90	100	30	50
	9	0	0	190	100	65	25	80
	10	0	25	185	80	85	20	60
	15	2	20	180	90	80	10	70
	4	0	15	180	90	75	15	75
	4	0	30	180	90	60	30	60
	2	0	5	170	60	80	30	95
	14	2	55	165	90	65	10	50
	2	0	5	160	90	60	10	105
	4	0	90	155	90	55	10	25
	10	0	30	145	110	25	10	95
	2	0	0	120	90	25	5	130
	13	2	25	120	90	30	0	125
	10	0	amputated					
Age 2–15 years	7	0	normal					
complicated cases	15	1	0	220	100	90	30	50
	5	1	20	195	100	85	10	55
	7	0	40	170	100	55	15	60
	2	0	25	145	90	35	20	100
	2	0	60	155	90	20	45	55
	13	0	5	120	90	30	0	145
	5	2	80	100	65	30	5	90
	5	1	20	40	20	20	0	210
Age 16–49 years	18	1	10	240	110	70	60	20
uncomplicated cases	19	0	0	225	90	90	45	45
	24	1	0	215	110	80	25	55
	29	0	15	210	110	70	30	45
	19	0	30	210	90	95	25	30
	49	1	10	190	100	90	0	70
	20	1	30	171	80	90	1	69
	17	2	25	170	60	90	20	75

Table 3 (cont.)

Tendon grafts in the fingers 77 cases	Age at operation	Lesion of digital nerves	Extension defect in the distal phalanx	Mobility of the distal phalanx	Mobility in the MP joint	Mobility in the proximal IP joint	Mobility in the distal IP joint	Flexion defect in distal phalanx
	24	1	35	165	100	60	5	70
	27	1	115	140	120	10	10	15
	19	2	90	140	90	50	0	40
	49	1	5	135	85	40	10	130
	17	1	25	120	90	30	0	125
	22	2	90	115	100	15	0	65
	19	1	25	110	80	30	0	135
	27	1	130	110	90	20	0	30
	18	1	65	105	90	5	10	100
	16	2	170	100	90	5	5	0
	33	1	45	85	70	0	15	140
	22	1	30	80	80	0	0	160
	42	0	105	55	45	5	5	110
Age 16–49 years complicated cases	19	1	20	180	110	70	0	70
	21	0	80	170	90	70	10	20
	28	0	2	170	90	80	0	93
	33	0	0	170	110	60	0	100
	40	2	70	160	90	65	5	40
	18	2	30	160	100	50	10	80
	19	2	25	165	80	70	5	90
	29	1	45	155	100	30	25	70
	31	2	20	150	90	60	0	100
	27	1	40	150	90	30	30	80
	29	1	45	150	70	70	10	75
	18	2	75	145	100	45	0	50
	31	0	75	140	90	40	10	55
	29	1	5	135	110	5	20	130
	19	0	35	125	70	50	5	110
	28	0	2	115	90	25	0	153
	25	2	30	95	90	0	5	145
	39	2	105	90	90	0	0	75
	40	0	45	90	90	0	0	135
	25	2	60	80	80	0	0	130
	22	2	70	70	45	10	15	130
	18		amputated					
	28		re operated (tendon rupture)					

Table 3 (cont)

Tendon grafts in the fingers 77 cases	Age at operation	Lesion of digital nerves	Extension defect in the distal phalanx	Mobility of the distal phalanx	Mobility in the MP joint	Mobility in the proximal I P joint	Mobility in the distal I P joint	Flexion defect in distal phalanx
Age 50 and over *uncomplicated*	52	0	20	150	90	40	20	100
Age 50 and over complicated	50	2	20	145	90	65	0	105
	60	2	15	125	110	15	0	130
	66	1	20	90	80	10	0	160
Isolated injury to flexor digitorum profundus	25	2	30	205	90	90	25	35

with the wrist in a position of function the flexion defect of the distal phalanx may be calculated as 270 (normal mobility) subtracting (extension defect + flexion)

The results are listed in tables stating for each case the age at the time of operation and whether the tendon injury co existed with injury to 1 or 2 digital nerves The individual cases are arranged according to the results obtained. The age groups 2–15 years 16–49 years and older than 50 years are listed separately and each age group is divided into 2 sub groups depending upon whether there was a case of a clean cut without complicating injuries or whether there was a crush injury and/or complicating injuries

In recording the operated thumbs the table gives the total extension defect in the distal and proximal phalanges the excursion in the proximal joint and the excursion in the distal joint In addition the latter is stated in degrees Because of the difficulty in recording the mobility of the carpo metacarpal joint accurately in degrees the restriction of the spread of the interstice (measured from the tip of the thumb to the tip of the index finger—compared with the other hand) was measured and so was the distance from the pulp of the thumb to the base of the little finger during opposition

RESULTS

In assessing the results for the 4 fingers Littler s criteria were used (excellent = 240 flexion + full extension good = 180) It was found that in the age group 2–15 years (clean cuts) there were 11/19 = 57 per cent good results in the same age group but with complicating injuries there were 3/9 = 33 per cent good results In the age group 16–49 years (clean cuts) there were 6/21 = 27 per cent good results

Table 4 Tendon grafting to flexor pollicis longus (18 cases)

	Age (years)	Lesion of digital nerve	Extension defect in proximal joint + Extension defect in distal joint	Mobility in the distal joint in degrees	Mobility in the distal joint in degrees	Mobility in the proximal joint in degrees	Distance in cm from the pulp of the thumb to base of the little finger in opposition	Lack of full spread in the first interstice measured in cm
Uncomplicated cases	19	0	0	45	0/45	45	1	0
	5	0	−15	45	−15/30	25	1½	1½
	7	0	0	45	0/45	25	1½	1½
	13	0	20	70	20/90	70	0	?
	14	0	−10	0	−10/−10	45	1	0
	21	1	0	15	0/15	40	2	4
	19	1	0	45	0/45	60	0	4
	20	1	0	10	0/10	45	1½	0
	46	2	10	30	−20/10	15	3	0
	15	2	5	15	5/20	20	1½	3½
Complicated cases	39	2	−10	35	0/35	45	1	0
	10	2	0	45	0/45	35	1	2½
	36	1	10	15	0/15	15	1	3½
	33	0	15	55	10/65	30	0	3
	19	0	0	20	0/20	20	3	3
	48	2	no active movement				5	1½
Age 50 years and over	52	1	0	35	0/35	35	1	0
	60	2	20	5	0/5	25	1	3½

and in the same age group with complicating injuries 1/23 = 4 per cent good results In the over 50 group there were a total of 0/4 = 0 per cent good results In the one case having grafting for an isolated injury *to the flexor digitorum profounds the result was good In the 18* cases treated by grafting to the flexor pollicis longus the results were in 3 cases better and in 4 cases equally good as if no operation had been performed the remainder were poorer

DISCUSSION

The operative results reported in the literature have been recorded partly by measuring the excursions in degrees and partly by measuring

the restriction of movement stated as the distance from the finger pulp to the distal crease of the hand and the distance from the finger nail to the level of the metacarpal bone in maximum flexion and maximum extension of the finger At times the two methods have been combined It is common to both modes of recording that they are suited rather for comparing the operative results in uniform materials than for affording a consistent characteristic of the individual material Modes of recording which state the results in centimetres give too favourable results in cases of small hands with short fingers A total excursion measured in degrees gives no information about the distribution of the mobility of the individual joints or about the site in the joint concerned in which the movement takes place Both bear relation to finger function Complete recording of these factors is difficult to survey both when tabulated and illustrated in diagrams

Recording the mobility of the thumb in degrees involves the difficulty that it is hard to obtain an accurate measure of the excursion of the movement in the carpo-metacarpal joint Many surgeons use the excursion in the distal joint as a measure of tendon function However it is well known that the position in the proximal joint influences the extent of the excursion and moreover the thumb may often be extended in the proximal and distal joints while there is a decrease in the width of the first interstice in maximum extension and abduction in the carpo metacarpal joint This factor is of importance to thumb function In the present study therefore the author decided to record the decrease *in the width of the first interstice while simultaneously record* ing the excursion of movements in the joints in degrees

The results were most favourable in the group having clean cuts and better in the under 15 age group than in older patients In patients over 50 years of age the results were poor Tendon function does not appear to be dependent upon whether nerve injury is present in the operated finger and it could not be demonstrated that better results were obtained in some categories of fingers than in others If operation is performed within the first months after the accident the operative results appear to be identical One patient had the operation several years after the original trauma and the result was poor Furthermore the importance of who performs the operation has been demonstrated As Fullbright lecturer the late American Professor H Allen operated upon a number of patients of all preoperative categories with good results in two thirds

In assessing the functional result however one should not rest con

tent with paying regard to the isolated tendon function As far as function is concerned an extension defect and restricted width of the first interstice give rise to more complaints than does a flexion defect

Moberg et al have correctly pointed out the role of sensibility and in particular tactile gnosis in hand function The patients often complain that a stiff finger is in the way but the fact is that they are unable to orientate this finger unaided by vision A finger which does not have full sensibility on the apposition surface is not used if another finger with normal sensibility is available Only in one out of the 29 cases of nerve repair (in a child) did the sensibility prove near normal with a 2 point discrimination of less than 4–5 mm and even in this case the patient did not use the finger an index finger for precision grip The remaining patients showed varying degrees of hyp and dys aesthesia somewhat better than in cases where the nerve had not been repaired In all cases but one there was protection sensibility both in cases where the nerve had been repaired and in others where it had not In 4 of the cases treated by pulley reconstruction the pulley had given way leaving the tendon like a sail on the volar aspect of the finger

Actual operative complications were observed partly in connection with the operation proper and partly in removing suited donor tendons In the former group there were 3 cases of taut volar scars 2 cases of injury to functioning finger nerve 1 case of injury to the ulnar nerve (pressure by a Pean forceps) and in 1 case posttraumatic dystrophy In addition there was a case of granuloma on the finger pulp left by a pull out wire and a cleft thumb nail after drilling of the tendon into the distal phalanx

The complications in removing donor tendons comprise 3 cases of annoying drop toe 4 cases of annoying paraesthesiae on the foot through many years 2 cases of transient paraesthesiae in the area innervated by the median nerve and one case of neuroma affecting the cutaneous branch of the radial nerve

It is evident from the above that our results are poorer than they ought to have been In the literature there are reports of up to 90 per cent good results in the best risk categories The surgeons have been experienced the technique has been the current one in hand surgery at the time of the operation and physiotherapists ergotherapists as well as an up to date bandage workshop have been available

In 1950 *Boyes* published a material of free tendon grafts divided into groups of about 25 treated in each year This analysis showed that of the patients from the first year less than 50 per cent could flex up to

1½ inches from the distal crease of the hand and that 2 operations were complete failures while among the patients from the last year of analysis 86 per cent had the above mentioned function This result was attained without any change in technique except that the surgeon had acquired greater skill

With the number of free tendon graftings indicated every year in this country each hospital will have only a very few cases

In Ugeskrift for Læger No 35 1967 it is concluded in an editorial that nerve repair must be considered a task for specialists and that this will be even further accentuated by the constant advances in suturing technique

The present analysis supports the view that free tendon grafting just like nerve repair must be considered a task for specialists which ought to be centralized in a few departments Only in this way is it possible to acquire and maintain the experience and routine necessary to obtain good results

SUMMARY

The results of 95 free tendon graftings are reported 18 were to the flexor pollicis longus 76 were done in injuries to the flexor digitorum profundus and sublimis and one in the case of an isolated injury to the flexor digitorum profundus in the tendon sheath By the criteria of Littler there were 57 per cent good results in uncomplicated cases (clean cuts) and 33 per cent in complicated cases in the age group 2–15 years The corresponding values in the age group 16–49 years were 27 per cent and 4 per cent respectively In the over 50 group the values were 0 out of 4 Among 18 cases of grafting to the flexor pollicis longus the function of the thumb had all considered improved in 7 The mode of recording and the role of complicating injuries in the functional result are discussed Operative complications of importance occurred in 16/95 The surgeon s share in the operative result is established

It is concluded that free tendon grafting is a task for specialists which ought to be centralized in special departments

RESUME

Les résultats de 95 greffes libres de tendons sont rapportes 18 ont été pratiqués pour le long fléchisseur du pouce 76 à la suite de lésion du fléchisseur profond les doigts et un dans le cas d une lesion isolee du fléchisseur profond les doigts dans la gaine du tendon D apres les

criteres de Littler, les resultats ont ete bons dans 57 pour cent des cas sans complications (coupe nette) et dans 33 pour cent des cas compliques dans le groupe d'age de 2 à 15 ans Les donnees correspondants dans le groupe d'age entre 16 et 49 ans ont ete respectivement 27 et 4 pour cent Dans le groupe des personnes de plus de 50 ans les données ont ete 0 sur 4 cas Parmi 18 cas de greffes du long flechisseur du pouce la fonction a eté amelioree chez 7 malades tout pris en consideration Il est discute du mode d'observation et du role des lesions compliquées pour le resultat fonctionnel Des complications operatoires importantes ont ete observees dans 16 des 95 cas La question de l'habilete du chirurgien pour le résultat operatoire est établie

Il est conclu que la greffe libre des tendons doit etre réalisée par des specialistes que l'on devrait centraliser dans des services spéciaux

ZUSAMMENFASSUNG

Die Ergebnisse von 95 freien Sehnentransplantationen werden berichtet 18 wurden am Flexor pollicis longus 76 bei Beschädigung des Flexor digitorum profundus und sublimis und eine bei einer isolierten Beschadigung des Flexor digitorum profundus in der Sehnenscheide vorgenommen Gemäss der Beurteilung nach Littler wurden 57 Prozent gute Resultate bei den unkomplizierten Fällen (reine Schnittwunden) und 33 Prozent bei komplizierten Fällen in der Altersgruppe 2–15 Jahre erhalten Die entsprechenden Werte in der Altersgruppe 16–49 Jahre waren 27 Prozent beziehungsweise 4 Prozent In der Gruppe über 50 Jahre waren die Werte 0 bei 4 Patienten Von 18 Fällen mit Transplantation zum Flexor pollicis longus war die Funktion des Daumens in 7 gebessert Die Art der Darstellung und die Rolle von komplizierenden Schaden auf das funktionelle Endresultat werden besprochen Operative Komplikation von Wichtigkeit traten in 16/95 Fällen auf Der Anteil des Chirugens in den operativen Ergebnissen wird festgestellt

Man schliesst dass freie Sehnenverpflanzung eine Aufgabe fur Spezialisten ist die in besonderen Abteilungen zentralisiert sein sollte

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OSTEOTOMY IN DEGENERATIVE AND RHEUMATOID ARTHRITIS OF THE KNEE JOINT

By

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INTRODUCTION

Osteotomy in the region of the knee joint has been described for about a century. Only during the last ten years though have significant reports appeared on its use for degenerative arthritis and less often for rheumatoid arthritis. This recent development signifies a different aim for the operation. The older aim was essentially the correction of static deformities including valgus, varus or recurvatum, or the correction of flexion contractures of functionally significant degree. The aim in the treatment of rheumatoid and degenerative arthritis encompasses positional improvement of course, but relief of pain is also hoped for and alteration of mechanics and of bone circulatory pattern so that a continuing disease process in the knee joint will be retarded, arrested or to some degree turned back.

A clinical Lecture on Antiseptic Osteotomy by *Macewen* appeared in Lancet in 1878 (*Steindler* 1940). From the textbook by *Jones & Lovett* (1924) it appears that at the turn of the century osteoclasis was still accepted, particularly in children, as well as forceful closed distal femoral epiphysiolysis. Of the latter the authors say: "In unskilled hands it is definitely dangerous." Osteotomy through limited incisions or by means of driving a chisel straight in through the skin is also described here. For arthrosis deformans debridement or arthrodesis is described and osteotomy is not mentioned.

Osgood in 1913 published a report of brief experience with supracondylar femoral osteotomy for permanent knee flexion contracture. Wedge removal was performed and either a green stick or complete fracture of the posterior cortex made. *Milch* in 1934 also favored

osteotomy leaving one cortex un osteotomized He emphasized that in unsuccessful supracondylar femoral osteotomy one cause is that the original angular deformity is not corrected but only compensated He also emphasized that in osteotomy one must make certain that the upper and lower tibial articular surfaces are parallel to each other and perpendicular to the shaft

Many types of osteotomies have been described with or without wedge removal or wedge addition (*Agerholm* 1960 *Smillie* 1962 *Chmesco & Antonesco* 1964) Simple linear osteotomy with angular displacement has been used in degenerative arthritis (*Wardle* 1962 1964) as has the ball and socket type (*Jackson & Waugh* 1961) The osteotomies applicable to the subject of this paper are wedge osteotomies (*Torgerson* 1965 *Gothefors & Hult* 1964 *Coventry* 1965) or those of the telescoping type

MATERIAL AND METHODS

Patients with rheumatoid or degenerative arthritis of the knee joint who during the ten years from 1956–1965 were subjected to osteotomy of the distal femur or proximal tibia at the Orthopaedic Department of Malmo General Hospital have been re examined Twenty eight knees were operated in twenty eight patients Six of the patients had died before the time of the final follow up examination The result of operation in these six cases was evaluated through study of the X rays and the clinical record The rest of the patients came for examination and were evaluated clinically and roentgenographically Follow up time varies between one and ten years with a median time of four and one half years Eleven patients had rheumatoid arthritis and seventeen degenerative arthritis (Table 1) The median age at operation was 63 7 years with the oldest 76 and youngest 50 The age breakdown is shown in Table 2

Table 1 Material

	Male	Female
Rheumatoid arthritis	2	9
Degenerative arthritis	6	11

Table 2 Age breakdown

	50–59	60–69	>69
Rheumatoid arthritis	4	5	2
Degenerative arthritis	7	2	8

Table 3 Deformity

	Valgus	Varus	Extension defect
Rheumatoid arthritis	8	2	1
Degenerative arthritis	7	10	2

Table 4 Osteotomy site

	Tibia	Femur
Rheumatoid arthritis	2	9
Degenerative arthritis	10	7

Table 5 Results

	Improved	Unimproved	Not evaluated
Rheumatoid arthritis	2	8	1
Degenerated arthritis	10	7	

In fifteen cases the deformity consisted of valgus deformity in twelve of varus and in one of a fixed extension defect In two cases varus or valgus correction were performed together with correction of an extension defect (Table 3) Valgus deformity was most common in rheumatoid arthritis varus in degenerative arthritis The surgery was performed by a number of different surgeons and the technique varied Twelve of the osteotomies were in the proximal tibia and sixteen in the distal femur (Table 4)

RESULTS

The results have been divided into two groups improved and unimproved In the first group are patients whose pain was gone or clearly decreased and whose walking ability was significantly improved All other patients were judged as unimproved Ten of the seventeen patients with degenerative arthritis were improved and only two of eleven patients with rheumatoid arthritis (Table 5) One patient died of pulmonary tuberculosis three months after surgery and so could not be evaluated The other five patients who died died between six months and six years after operation Three of the six patients who died had rheumatoid arthritis three degenerative arthritis All of the patients that died were over 67 years (average 72 2)

Local complications occurred in six cases In three cases dislocation of the osteotomy occurred and in one of them re-operation with internal fixation was needed All of these three were in telescoping supracondylar femoral osteotomies without internal fixation Three pseudarthroses occurred requiring re-operation one in the distal femur two in the proximal tibia

The range of flexion in the knee joint was only in four cases less than 90 where it was 90 or more pre-operatively These four had significantly decreased motion after operation Three of them were supracondylar and one proximal tibial osteotomies In two of the cases pseudarthrosis had occurred and in one postoperative dislocation

of the fragments In one case synovectomy was performed at the same time as supracondylar femoral osteotomy

DISCUSSION

Improvement after surgery has taken place in fewer than half of our cases The patients with rheumatoid arthritis have noticeably responded poorly to osteotomy The patients evaluated as improved have however shown a very significant improvement Other authors have presented good results in many cases (Table 6) Choice of indications for osteotomy and of surgical technique are of considerable significance in obtaining good results and through uniformity and discrimination in these factors the value of osteotomy should increase considerably

Osteotomy in rheumatoids is only sparsely described in the literature (Coventry 1965) Of the eleven cases in our series only two showed significant improvement These patients had symptoms chiefly localized to a knee joint with pronounced deformity while the other joints were rather well preserved and the patients general condition was good The remaining patients in this group were severely incapacitated in several joints and the operated knee showed pronounced destruction pre operatively When surgery is planned in these advanced cases arthrodesis should be strongly considered In a few cases synovectomy was performed together with osteotomy These patients became pain free but motion was severely limited It does not seem advisable to carry out these operations together because osteotomy demands a period of immobilization while early mobilization is desirable after synovectomy In one case surgery produced improved walking and weight bearing ability on the operated extremity which led to rapid destruction with central dislocation of the already disease destroyed hip joint The hip joint requires special evaluation before considering knee osteotomy Of special significance are abduction and adduction ability because correction of valgus or varus deformity results in an altered axis in the hip joint with walking

The results of osteotomy in degenerative arthritis were better than in the group with rheumatoid arthritis In the cases which did not improve the cause was pronounced destruction preoperatively in the operated knee co existing difficulty with other joints (hip ankle) or complications in the form of delayed union or dislocation of the osteotomy The cases suitable for surgery are those with significant

valgus or varus deformity with destructive changes and symptoms from the concave side of the joint and in which the range of motion is at least 60-70

The surgical technique varied in our cases The determining factor for whether distal femur or proximal tibia osteotomy was chosen was the joint surface The surfaces of the ankle joint and knee joint should be parallel (Figure 1) In tibial osteotomies done more recently a wedge was removed proximal to the tibial tuberosity and fixation was achieved with staples (Figure 2) Good fixation was obtained in this way and plaster fixation was required for only about four weeks after which joint motion training was possible In the two cases with pseudarthrosis of the tibia osteotomy was distal to the tuberosity and internal fixation was not used

Most of the distal femoral osteotomies were of the so-called telescoping type (Figures 3 and 4) Dislocation took place postoperatively in three and pseudarthrosis in one This high complication rate can be explained by technical errors It is very important that the osteotomy be made sufficiently distally so that the tip of the shaft fragment is located immediately above the broadest portion of the condylar flare The point is located on the deformities convex side On the concave side a cortical bridge of about 2 centimeters width is preserved and not osteotomized This bridge is broken as the deformity is corrected by means of pressing the point of the shaft fragment into the condylar fragment In this way the position is so stable that internal fixation is not required A plaster from groin to toes is applied

The benefit from osteotomy in the knee region that is due to correction of distorted weight bearing and thus to correction of excess lo-

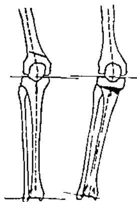


Figure 1 Level of osteotomy when the deformity is situated above the knee (A) and below the knee (B)



Figure 2 X ray of a wedge osteotomy of th proximal tibia

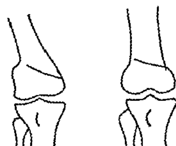


Figure 3 Schematic drawing of supracondylar femoral osteotomy of the telescoping type



Figure 4 X rays of a supracondylar femoral osteotomy of the telescoping type

calized compression and of instability needs no further explanation It has further been suggested that pain relief is due to relief of intra medullary venous pressure (*Wardle* 1964) improvement in the nutrition of the articular cartilage (*Smillie* 1962) and alteration of the vascular network (*Trueta* 1962) The comments regarding vascular improvement are similar to those made about proximal femoral osteotomy for degenerative arthritis of the hip and similarly one finds reports of steadily improving knee cartilage space and reversal of roentgenological signs of subchondral changes (*Jackson & Waugh* 1961 *Wardle* 1962 1964) Whichever explanations are ultimately accepted the operation seems of great value when done with the proper indications and surgical technique

Author		X ray improvement
Jackson &	ed	Joint sclerosis decreased in 2 cases 1½ and 3½ years after operation
Wardle	in 14 cases	Cysts improve time not *specified*
Wardle	least 90 by	Joint space increases over 5 years
Veenemans	ed	No changes occur Time not specified
Gothefors &		
Coventry	with full *tension in 18*	Not specified

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From the Orthopaedic Hospital Copenhagen Department I (Head Professor A Bertelsen M D) and Department II (Head E Hjalmar Larsen M D)

CONGENITAL ANGULATION OF THE LOWER LEG

Crus Curvatum Congenitum

By

K Skou Andersen H Bohr & O Sneppen

Received 25 vi 67

Congenital angulation of the lower limbs makes up a rare and ill defined syndrome which may be the precursor of so-called congenital pseudarthrosis of the tibia

Since *Camurati*, in 1930 published his report on these conditions there has been an increasing number of reports but the designations have differed e g intrauterine fracture crus varum congenitum congenital bent tibia congenital angulation of tibia the kyphoscoliotic tibia and congenital pseudarthrosis of the tibia

Since the aetiology of these congenital angulations is unknown the syndrome is only a clinical concept maintained chiefly because of the risk of pseudarthrosis

Froelich (1910) stated that this pseudarthrosis was not always congenital but often resulted from fracture of the lower leg which had been bowed from birth According to *Kosic* (1941) pseudarthrosis developed only in anterolaterally convex legs his term referring to the entire condition was crus varum congenitum Other directions of angulation are more uncommon but may also give rise to pseudarthrosis (*Camurati* 1930)

Büttner & Eysholdt (1950) do not feel that it is possible to decide with certainty whether all congenital angulations of the lower leg make up a pathogenetic entity According to *Lindemann* (1961) there is not however much doubt that intrauterine fracture crus varum congenitum and the congenital pseudarthroses of the tibia are pathogenetically closely related

At our present stage of knowledge it seems reasonable to collect all

cases of congenital angulations of the lower leg under one common designation.

Lindemann in 1961 suggested the term crus curvatum congenitum (c. c. c.) meaning all congenital angular deformities of the lower leg in so far as the more systemic diseases of bone could be ruled out. This term will be used here.

Interpreted in this way, c. c. c. makes up a characteristic syndrome. It is most often unilateral, although bilateral cases have been reported, e. g. by *Camurati* (1930) and *Ducroquet & Cottard* (1939). The angulation is present at birth or appears within the first days of life. It nearly always affects the distal half of the lower leg, the most characteristic site being at the junction of the middle and distal third. Radiography often shows thickening of the cortex on the concave aspect of the bone on a level with the apex of the angulation. At times there are cystic changes or fracture of the bone at the site of the angulation. While these changes are invariably present in the tibia, the fibula may be radiologically normal. As a rule, however, it shows the same changes as the tibia. In certain cases the fibula may be absent, and these cases have sometimes been classified in a separate group (*Farmer* 1960). Since they are accompanied in the majority of cases by angulation of the tibia, and since pseudarthrosis has been described in this group too (*Aitken* 1959), it seems reasonable to assign them to c. c. c.

Previously, most interest was devoted to the aetiology and treatment of the congenital pseudarthroses of the tibia. We felt that it must be of interest to elucidate the prognosis of c. c. c. with a view to spontaneous correction of the angulation and to the risk of pseudarthrosis.

MATERIAL

During the period 1934–1966 a total of 40 cases of c.c.c. were treated in the Orthopaedic Hospital, Copenhagen.

Twenty patients were seen in the hospital for the first time within the first 8 weeks of life and only 11 patients were over one year of age when first seen. In all cases the angulation had been present at birth.

The follow-up period ranges from 6 months to 32 years, average 13.5 years. When the analysis was completed about new year 1966–1967 6 patients were under 5 years of age, while 8 were from 5 to 10 years, 7 from 11 to 15 years and 19 were over 15 years of age.

The sex distribution is given in Table 1. There was only one bilateral case and of the remaining 39 cases 20 were right sided and 19 left sided.

To divide the cases of c.c.c. into sub-groups as uniform as possible from the

Table 1 Distribution of Crus curvatum congenitum by sex and type of angulation

Sex	Type of angulation		
	Anterior *with* associated congenital deformities	Anterior *without* associated congenital deformities	Posterior
Female	5	7	6
Male	16	3	3
Total	21	10	9

prognostic point of view we felt that it would be expedient, as done by *Heymann* (1949) to distinguish between cases with anterior angulation without associated congenital deformities cases with anterior angulation with associated congenital deformities and cases with posterior angulation

The angulation of the antecurved legs was most often antero lateral convex or purely anteroconvex In the group without other associated deformities all 10 cases were antero laterally convex In the group with associated deformities the angulation was in 4 cases antero laterally convex in 10 cases purely anteroconvex In 4 cases the angulation was antero medially convex

Of the cases with posterior angulation 8 were postero medially convex and one postero convex

Patients with c c c often have other congenital deformities Among the 40 cases of c c c there were 29 with hypoplasia of the ipsilateral lower limb 19 had congenital deformity of the ipsilateral foot 6 had dimpling of the skin and 8 had a congenital constricture at the site of the angulation In 12 cases there was aplasia of the ipsi lateral fibula and in 3 syndactyly of fingers

Out of the 31 cases with anterior angulation 6 had a congenital constricture and 5 dimples in the skin In 12 there was aplasia of the fibula In 8 of these latter cases there was also absence of either the 5th or the 4th ray in the foot. 6 patients had congenital equino valgus foot one congenital equino varus In 2 cases there was such pronounced hypoplasia of the foot that it presented merely as a lump without definite ossification

Out of the 9 cases with posterior angulation 2 had associated congenital constric tures 1 had dimpling of the skin 1 had calcaneo valgus and 1 pronounced hypo plasia of the foot without ossification

Two factors are of essential importance to the functional ability obtainable in c c c One is the degree of hypoplasia and the attendant shortening and the other is the occurrence of fractures and their tendency to unite

Hypoplasia is present in varying degree in c c c Among 17 cases seen at birth or shortly after 7 had mild hypoplasia with up to 1 cm shortening of the lower leg 6 had 2–3 cm shortening and 4 more than 4 cm shortening

Hypoplasia occurred in legs with anterior as well as posterior angulation Out of 31 patients with anterior angulation 20 exhibited considerable hypoplasia and shortening And among these 20 cases the hypoplasia was so marked in 8 that in combination with a deformed foot it made up an indication for amputation In 3 cases epiphysiodesis of the contralateral leg had to be performed

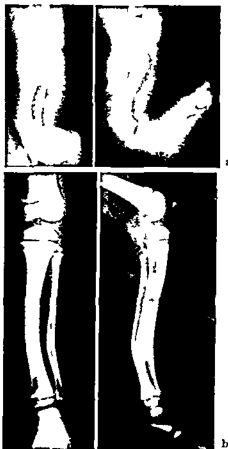


Figure 1 a + b OH 983/6 The spontaneous correction in a Crus curvatum congenitum with posterior angulation a) at the beginning of follow up b) 4 years later

Out of 9 patients with posterior angulation 8 had hypoplasia of major degree Five required epiphysiodesis and one patient was fitted with a Syme prosthesis.

The tendency for the angulation to become spontaneously corrected was assessed by measuring the angulation in X ray films from the beginning and from the end of the follow up period In this connection it should be mentioned that the material is derived from a period of more than 30 years and therefore the therapeutic principles in respect to correcting the angulation have not been uniform throughout. A number of cases had been treated by corrective casts while others had had osteotomy or therapeutic fracturing

In the 9 patients with posterior angulation primary examination showed angulation in the sagittal plane ranging from 105 to 170 average 150 In 2 cases the bone was fractured at an early stage of the follow up period in an attempt to correct the angulation The others have been followed for 4–19 years At the end of the follow up period 6 of these patients showed satisfactory appearances (less than 10 angulation) In one case the angulation exceeded 10 but this patient had been followed for only 4 years during which spontaneous correction from 105 to 160 had occurred (Figure 1)

In the 31 cases with anterior angulation the angulation was 90 -170 at the primary examination After a short follow up period osteotomy was done in 3 cases and fracturing of the lower leg in one in an attempt of correction In 2 cases the follow up period had been only 6 months so that it is not possible to assess the tendency to correction In the remaining 8 cases the follow up period ranged from 4-2? years Four obtained a satisfactory appearance with an angulation of less than 10 In 4 cases the angulation exceeded 10 at the end of the follow up period.

The most serious complication of c.c.c is fracture and pseudarthrosis The fracture may be present at birth or it may occur within the first years of life Our material includes 3 cases in which fracture was diagnosed immediately after birth In 3 fracture occurred within the first year of life and in 6 within the 2nd-5th year of life In another 3 cases therapeutic fracturing was done a few weeks after birth

This gives a total of 15 fractures among the 40 cases of c.c.c Out of these fractures 11 developed into pseudarthroses.

Out of the 3 fractures present at birth one developed into pseudarthrosis Out of the 9 fractures occurring after birth all ended as pseudarthroses One of the 3 therapeutic fractures developed into pseudorthrosis (Table 2)

Table 2 Cases with fracture and pseudarthrosis by type of curvation

	Type of angulation		
	Anterior *with* associated congenital deformities	Anterior *without* associated congenital deformities	Posterior
Total number of cases	21	10	9
Number of cases with fracture	3	10	2
Number of cases with pseuarthrosis	1	10	0

Corrective osteotomy was carried out in 4 cases—three with anterior angulation with associated deformities and one with posterior angulation In all 4 cases the osteotomy healed within the normal time

Some authors e g *Moore* (1949) and *Badgley* (1952) feel that on the basis of the X ray films they can pick out the prognostically unfavourable types claiming that thickening of the cortex on the concave aspect of the angulation with consequent partial or complete obliteration of the medullary canal predisposes to pseud arthrosis However *Exner* (1957) and *Mal en* (1955) are sceptical of the pathogene tic significance of this X ray finding

Thickening of the cortex on the concave aspect of the bone was present in 26 of our cases. Partial obliteration of the medullary canal was found in 13 8 of whom had complete obliteration Only 3 of these 8 patients developed pseudarthrosis

Cystic changes at the site of the angulation have often been reported *Compere* (1936) published a case in which he believed the pseudarthrosis to be due to localized osteitis fibrosa *Green & Rudo* (1943) who also found cystic changes



Figure 2 Case of Crus curvatum congenitum with anterior angulation and development of fracture in a cystic tibia within 4 months

claimed that these were intraosseous neurofibromas However this claim has not been confirmed (*Boyd* 1958) In 4 of our cases the first X rays showed cysts in the tibia All later developed pseudarthrosis (Figure 2)

The angulation of the lower leg in the sagittal plane ranged from 90 to 170 The magnitude of the angulation measured as the numerical degree could not be correlated to the risk of developing pseudarthrosis Among 9 cases with an angulation below 140 no pseudarthroses occurred Among 21 cases with an angulation of between 140 and 180 there were 4 cases of pseudarthrosis

Pathological studies of congenital tibial pseudarthroses have been described by *Camurati* (1930) His studies as well as numerous subsequent ones have shown that histologically the congenital pseudarthroses do not differ from other pseudarthroses *Green & Rudo* (1943) were the first to study a biopsy from a c c c before fracture and pseudarthrosis occurred This examination also failed to demonstrate specific histological features In our material biopsies from the site of pseudarthrosis were moved for microscopic examination in 4 cases subjected to operation for the pseudarthrosis but no notable findings were made In 4 cases microradiographic study of the biopsies was done and in 2 cases double labelling with tetracycline was done before removing the biopsies These investigations did not reveal any special features of the bony structure but in one case it seemed as if the rate of deposition of bone occurred faster than might be expected according to the patient s age (Figure 3)

DISCUSSION

The aetiology of c c c is unknown However there is presumably a relationship between congenital pseudarthrosis of the tibia and von Recklinghausen s neurofibromatosis as demonstrated by int al *Barber* (1939) and *Ducroquet & Cottard* (1939) One case of neurofibromatosis occurred in our series and this patient developed pseudarthrosis

On the basis of the numerous theories advanced Guillemin:t (1953) suggested a working hypothesis presupposing that the congenital



Figure 3 Section through the bone near the pseudarthrosis labelled with Tetracycline OII 4976/60

pseudarthroses of the tibia have invariably been preceded by segmental dysplasia or dystrophy This dysplasia may be due to systemic causes such as mesenchymal damage neurofibromatosis endocrine distur bances or to local causes such as a reduced blood flow through the part or intrauterine mechanical factors This hypothesis comprises all known aetiological factors and seems to be at present the most accep- table one Whether it can also embrace all cases of c c c is not clear

Clinically a distinction may be made between several types of c c c Like *Badgley* (1952) we found cases with anterior angulation to be most common In *Badgley s* series as well as in ours they constituted about 75 per cent Cases with posterior angulation made up about 25 per cent Both types are equally often associated with other congenital deformities viz in about one third

From the prognostic point of view the three groups anterior angu lation without associated congenital deformities anterior angulation with associated congenital deformities and posterior angulation are fairly sharply separated Fractures ending in pseudarthrosis were by far most common in the group with anterior angulation without associated deformities In Badgley s series this occurred in 1 out of 4 cases and in our series in all 10 cases

In the group with anterior angulation with other congenital defor mities *Badgley* found 1 pseudarthrosis among 10 and we had 1 among 21

In the group with posterior angulation *Badgley* had no pseudar

throsis among 5 cases and in our series too there was none among 9 cases.

Several workers have published cases in which the posterior angulation has become spontaneously corrected. *Heymann* (1949) as well as *Lindemann* (1961) stated that cases with posterior angulation differ clearly from the cases with anterior angulation partly in respect to spontaneous correction and partly in respect to the risk of pseudarthrosis. In our material some spontaneous correction occurred not only in the group with posterior but also in that with anterior angulation. Probably the correction was more marked among the patients with posterior angulation.

Like several others before us, we have found no reason to presume that radiological findings such as thickening of the cortex and partial obliteration of the medullary canal are of any independent prognostic importance. On the other hand we have found cysts to be a serious prognostic sign predisposing to pseudarthrosis. This observation too is in accordance with those of previous authors.

In further accordance with previous findings (int. al. *Heymann* 1949, *Thyge Madsen* 1956) we found dimpling of the skin and a congenital constricture at the site of the angulation to occur in anterior as well as posterior angulations. We found no evidence for assuming that c. c. c. with a congenital constricture or c. c. c. with dimpling of the skin make up separate groups in respect to the risk of developing pseudarthrosis.

Cases showing aplasia of the fibula have been set part by some workers as a separate group differing from c. c. c., presumably wrongly. In our series no case of pseudarthrosis occurred in the group having c. c. c. as well as aplasia of the fibula.

CONCLUSION

Cases of c. c. c. with anterior angulation without associated congenital deformities very often develop pseudarthrosis. The therapeutic principle must be to avoid fracture. No weight bearing should be allowed and any kind of osteotomy is contra-indicated. Repeated radiographic examinations should be done to detect cyst formation, if any, as this must be interpreted as a serious prognostic sign.

Cases of c. c. c. with anterior angulation and other congenital deformities seldom end in pseudarthrosis. In these cases deformities of the feet and hypoplasia call for treatment. Presumably the leg should

not be braced as in this group the hypoplasia is frequently a problem Correcting osteotomy should only be performed on strict indications

Cases of c c c with posterior angulation very seldom develop pseudarthrosis In these cases treatment is often required for foot deformities and hypoplasia Presumably bracing of the leg is unnecessary Osteotomy is rarely indicated The prognosis is on the whole favourable

SUMMARY

From 1934 to 1966 a total of 40 cases of congenital angulation of the lower leg here called crus curvatum congenitum (c c c) were treated in the Orthopaedic Hospital Copenhagen

The follow up period ranges from 6 months to 32 years

C c c is sometimes associated with other congenital deformities About three quarters of all the cases were anterior and one-quarter posterior angulations Associated congenital deformities were equally common in these two groups Hypoplasia was present in varying degrees

Fractures of the leg occurred in 15 cases Out of 10 cases of c c c with anterior angulation without associated deformities all had fractures with development of pseudarthrosis

Assessment of the X ray films appears to show cysts to be a serious prognostic sign in respect to pseudarthrosis all our 4 cases with cysts developing pseudarthrosis

An attempt to assess the tendency to spontaneous correction of the angulation showed that possibly this is most marked among the cases of posterior angulation

The principle of treatment must be to avoid fracture as far as at all possible In cases with associated congenital deformities treatment of foot deformities and hypoplasia is often required

RESUME

De 1934 à 1966 on a traite à l Hopital Orthopedique de Copenhague 40 cas d incurvation congénitale de la jambe (Crus curvatum congenitum = C c c)

La durée des observations varient entre six mois et 32 ans

La C c c est souvent accompagnée d autres déformités congenitales 3/4 des malades étaient des cas d antéincurvation et 1/4 de rétroincurvation La fréquence d autres déformités congénitales est la même pour les deux groupes De l'hypoplasie a été observée a des degrés variables

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From the Department of Roentgenology (Head G Sohrne) and Orthopaedic Surgery (Head T Jerre) Centrallasarettet Västerås Sweden

DISAPPEARING BONE DISEASE, MORBUS GORHAM

Report of a Case

By

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Received 21 v 67

Disappearing bone disease Morbus Gorham haemangiomatosis lymphangiomatosis massive osteolysis spontaneous absorbtion of bone phantom bone primary lymphangioma and cryptogenetic progressive localized osteolysis are various names for the same skeletal disease

The disease is characterised by osteolysis with bone disappearance and histologically pictures occur which are best interpreted as angiomatosis sometimes described as haemangiomatosis sometimes as lymphangiomatosis

The disease may affect only one bone but very often several adjacent bones are involved Histologically the picture is benign Malignant pathological tissue has never been observed Metastases have never been seen Deaths from the disease have been reported but then the process was localised to the rib bones or vertebrae and fatal complications arose owing to involvement of the pleurae and the spinal canal (4 9 10 11 17) As a rule the disease makes slow irregular local progress The osteolysis may however cease as inexplicably as it began No regeneration of the vanished bone has ever been observed Generally the process does not confine itself to one bone but attacks skeletal parts Spontaneous fractures are common The osteolysis often commences at a young age Boys and girls are affected about equally

Disappearing bone disease is not accompanied by general symptoms No endocrinal disturbance is present nor any apparent chemical blood changes except during acute phases when the alcaline phosphatases may show a moderate increase

The disease may affect all skeletal parts Only a few cases are reported involving the skull (12 21)

The diagnosis is made with the aid of radiology and biopsy. Considerable surprise is experienced when this disease is seen for the first time for there is very little discussion of it in current textbooks.

Arteriography has not been of any diagnostic aid but possibly an intraosseous injection of contrast medium may be of some use as the contrast medium is mainly collected in the angiomatous tissue. However no idea of the drainage conditions were obstained.

The earliest known publication is that of *Jackson* 1838 (13). His casereport concerned a man whose humerus underwent complete osteolysis. During the lengthy course of the disease he experienced repeated spontaneous fractures.

In 1955 *Gorham & Stout* described 2 cases of their own and compared the cases from previous publications, a total of 24 cases. They emphasized the haemangiomatosous tissue in the bone in the osteolysis zones. In 1956 (6) *Falkmer & Tilling* described a case of osteolysis in the lower region of the spine and adjacent parts of the pelvis in a man aged 55 where the histological picture showed lymphangioma in the osteolysis zones. No progress was seen in this case. At an X-ray examination in 1966 the condition was unchanged.

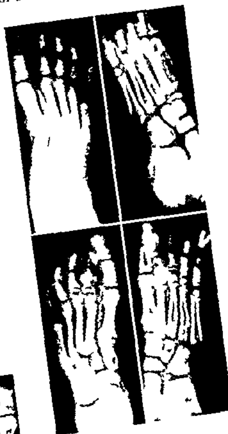
After the publications of Gorham and his colleagues (7, 8, 9, 20) more new cases have been published and the total number of cases now known approaches 100.

As we have observed another case of the disease we consider this worthy of publication.

CASE HISTORY

The patient was a girl born in 1954. There was nothing of interest hereditarily. At the age of 3 the girl sprained her left foot. The foot became swollen but the discomfort was not so great that a visit to the doctor was required. At the age of 5½ the Orthopaedic Department was consulted since the feet were of unequal growth, the left foot smaller with a tendency of hallux valgus deformity. At the X-ray examination of that time (Figure 1) metatarsal bones 1–4 and the phalanges to no. 2 and 3 toes were attacked by a concentric atrophy. The cancellous structure in the remaining bone was coarse. The girl was examined repeatedly during the course of 6 years. She had several spontaneous fractures (Figure 2) which healed with callus but the atrophy progressed constantly and even the callus formation underwent osteolysis. Figure 3 shows the condition after almost 6 years of observation. The disease also spread to a number of tarsal bones. The left foot is clearly smaller. The calf musculature is moderately atrophied (Figure 4). The 5th metatarsal bone and phalanges of the large toe are fairly well preserved. Discolouring of the skin was not observed. During acute phases with spontaneous fractures there was moderate pain and swelling. The patient manages well with protective arch support.

Figure 1 Appearance of unaffected right foot (above) and of left foot at first roentgen examination 1–4 metatarsals and phalanges in second and third toes show concentric atrophy The structure of the bone is partly loose Moderate hallux valgus Child 5½ years



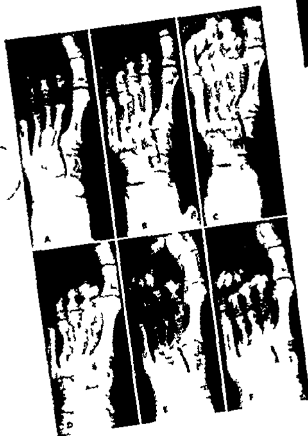


Figure 2 Frontal view of left foot during follow up A) 2 years B) 3 years C) 3 years 1 month D) 3 years 8 months E) 4 years and F) 4½ years Slow progress Spontaneous fratures partly healing with callus formation also affected by progressive osteolysis



Figure 5 The affected left foot and the unaffected right foot after 6 years observation Diaphysis of 4th metatarsal resected for biopsy Disease also affected several tarsal bones Phalanges of great toe as well as all 5 metatarsals are fairly well preserved

as the sole therapy and she is able to go to school normally Radiological therapy has been discussed but in view of the poor results previously reported we have not given such treatment

The remaining skeletal parts were normal the lung X rays normal and also the kidney examination The SR was normal as were the blood phosphorus serum albumin blood calcium and calcium in the urine Only the alcaline phosphatases were slightly raised during acute phases of the disease

After an observation period of four years an operation was carried out exstirpating the diaphysis of the 4th metatarsal bone for the purpose of histological examination At the operation the residual bone was roughened The articular cartilage was intact The tissue adjoining the bone was greyish yellow and no bleeding from this tissue could be ascertained at the operation

HISTOLOGICAL EXAMINATION

Large sections of the bone tissue were replaced by a loose partly angioma like tissue with numerous thin walled vessels predominantly constructed like lymph vessels (Figures 5 and 6) In various directions an obvious inflammatory element was present in the form of lymphocyte infiltration and here and there pictures of non specific granulation tissue were observed in association with partially necrotic bone showing osteoclastic bone resorption (Figure 7) There were no pictures of lymphangiomatous proliferation into surrounding soft tissues



Figure 4 Photograph of both feet after 5 years observation

DISCUSSION

In previous published cases the angiomatous tissue demonstrated at the histological examination very often resembled the haemangioma (2 7 8 9 11 15 17 20 23) Pictures resembling the lymphangioma were also described (4 6 22 23) Even a mixture of both types was found (10) Only a few authors saw osteoclasts in the histological picture (12 18) In our present case we discovered osteoclastic resorption

The case previously reported by *Fallmer* and *Tilling* and the present case offer similarities in the histological picture with lymphangiomatosis In both cases the operative findings with none or only slight bleed

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Figure 5 Bony tissue largely substituted by loose vascular and partly angiomatous tissue with numerous thin walled vessels of preponderantly lymphatic structure

Figure 6 The same as in Figure 5 but in higher magnification

Figure 7 Area with slightly chronic unspecific inflammation adjacent bone destruction with osteoclasts


5
6

ing from the pathological tissue may also support this diagnosis However, in other reported cases with lymphangioma of the bone the surrounding soft tissue was also invaded which is obviously not so in the present case (14) In discussing the pathogenesis two views may be presented

A The lesion may represent a primary angiomatous process that is be of neoplastic type Against this there are the characteristics mentioned above that the surrounding soft parts are evidently not involved and that the process is not expansive but atrophying In this respect it may be mentioned that the case reported by *Falkmer & Tilling (6)* which was reported in 1956 and followed up in 1966 did not show expansion of the process

B The lesion may represent an infectious or toxic bone injury with necrosis and resorption of bone tissue and also the development of granulation tissue of a non specific type with an abundance of vessels The persistence of this granulation tissue would possibly give its angiomatous character to the histological picture

The present case which throughout the observation period showed progress clinically is extremely interesting owing to the osteoclastic bone resorption demonstrated histologically and to the occurrence of an inflammatory process The case would thus perhaps offer some support to alternative B above

Typical of the radiological findings is the continuous progress of the disease over a long period very often invading adjacent bone but also leaving adjacent bone intact at other times

SUMMARY

A case is reported of disappearing bone disease in a girl observed for fully 6 years The osteolytic process affected a number of bones in the left foot As in previously described cases an angioma like tissue was found at the site of the affected bone In addition non specific granulation tissue and signs of osteoclastic bone resorption were present The last mentioned findings are briefly discussed from a pathogenetic view point

RESUME

Il est rapporté un cas de maladie comportant chez une fille une disparition d os Ce cas a été suivi pendant six ans Le processus ostéolytique touche un certain nombre d os du pied gauche Comme dans les

cas decrits anterieurement un tissu similaire a un angiome a ete trouve a l endroit de l os atteint De plus il y avait aussi un tissu de granulation non specifique et des signes de resorption osteoclastique de l os Il est discuté brievement des dernieres trouvailles mentionnees en partant d un point de vue pathogenetique

ZUSAMMENFASSUNG

Der Fall einer verschwindenden Knochenerkrankung bei einem Mäd chen das fur volle 6 Jahre beobachtet wurde wird berichtet Der osteo lytische Prozess befiel eine Anzahl von Knochen im linken Fuss Wie in früher beschriebenen Fallen wurde ein angiom ähnlishes Gewebe am Sitze des erkrankten Knochens gefunden Ausserdem waren noch unspezifisches Granulationsgewebe und Zeichen von osteoklastischer Knochenresorption vorhanden Die zuletzt erwähnten Befunde werden von einem pathogenetischen Gesichtspunkt aus kurz besprochen

ACKNOWLEDGEMENTS

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FRACTURE OF THE LATERAL PROCESS OF THE TALUS

Supination Dorsal Flexion Fracture

By

O Fjeldborg

Received 2 XII 67

While I was working at the Orthopaedic Hospital Aarhus Professor Thomasen asked me in connection with an analysis of his club-foot material to investigate the mechanical features of the normal foot Only one detail of this complex kinetic system will be described here

During supination the calcaneous turns in relation to the talus on an axis proceeding dorso medially from the neck of the talus downwards and postero laterally to the lateral surface of the tuberosity of the calcaneus (Figures 1 and 2)

This axis has been described by *Donti* (1903) *Brockman* (1930) *Thomasen* (1941) and others In this movement the calcaneous performs plantar flexion adduction and varus rotation as the angle between the talus and calcaneus is reduced

If small windows are cut into the joint capsule it may be seen that during maximum supination there is no congruence between the joint surfaces in the talo-calcaneal joint—as shown in Figure 2 and sketched in a somewhat exaggerated way in Figure 3 This phenomenon has previously been described by *Donti* (1903) who observed it using an entirely different technique

Thus a fracture of the lateral process of the talus may arise from a fall on the dorsally flexed supinated foot (Figure 3)

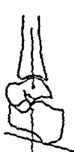
It might be anticipated that such a fracture would occur in three stages fissure (Figure 6) displaced fracture (Figure 7) and fracture with a supination dislocation in the talo-calcaneal joint the calcaneus being pushed forward in relation to the talus (Figure 8) Figures 4




Figure 1 Figure 2

Figure 1 Normal position of the talus and calcaneus Congruence between the joint surfaces

Figure 2 Supination in which the joint space gapes a bit posteriorly there being contact only at the site of the lateral process of the talus



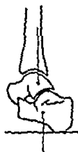


Figure 3 Figure 4 Figure 5

Figure 3 Fracture mechanism in the dorsal flexed supinated hindfoot To facilitate understanding the incongruence in the talo-calcaneal joint is exaggerated The weak spot of the system is the lateral process of the talus

Figure 4 A similar fall injury on a dorsally flexed foot but with the talo-calcaneal joint in the normal position in which the joint surfaces are congruent The weak spot is the neck of the talus

Figure 5 A fall injury on a foot in the normal anatomical position In this position the anterior edge of the tibia does not play any role There is congruence between the joint surfaces in the talo calcaneal joint The weak area is the body of the calcaneus

and 5 illustrate the relationship to two other types of fracture of the hindfoot

All this was still theory without confirming examples Later while I was in the Department of General Surgery of the Municipal Hospital Aarhus, I checked the X rays of all foot injuries for more than a year before discovering the first case (Figure 6)

A housewife aged 57 had fallen 1½ m and landed on a stone step





Figure 6 *Figure 7* *Figure 8*

Figure 6 Fracture of the lateral process of the talus stage 1 (fissure)

Figure 7 Fracture of the lateral process of the talus stage 2 (fracture with displacement of the lateral process of the talus)

Figure 8 Fracture of the lateral process of the talus stage 3 (with subtalar dislocation)

On admission she had swelling of the ankle region but no tenderness of the malleoli Passive movements in the subtalar joint gave rise to severe pain anterior to the lateral malleolus X rays of the right ankle joint supplemented by tomography revealed a fracture line without displacement through the lateral process of the talus (Stage 1) (Figures 9 and 10)




Figure 9 *Figure 10*

Figure 9 Fracture of the lateral process of the talus stage 1

Figure 10 Anteroposterior tomography of the same fracture as shown in Figure 9

After two months of treatment in a plaster cast the fracture united At follow up 18 months later the X ray appearances were normal and the patient had no complaints



Figure 11 Fracture of the lateral process of the talus stage 2

A fortnight after the first case Case 2 arrived A 60 year-old labourer had fallen 1 m after the ladder on which he had been standing broke There was swelling of the ankle region and distinct tenderness anterior to the lateral malleolus No tenderness of the malleoli X rays revealed a displaced fracture of the lateral process of the talus (Stage 2) (Figure 11)

The completely detached fragment of the process was removed surgically followed by immobilization in plaster for 8 weeks

At follow up 18 months later the patient was working but had slight osteoarthritic complaints Movements in the ankle joint and subtalar joint were slightly restricted and X rays showed apart from the missing lateral process of the talus some narrowing of the joint space in the talo calcaneal joint About 1 year after the first two patients Case 3 was admitted

A 63 year-old psychotic man had jumped out of a first floor window There was considerable swelling of the ankle region with severe tenderness of the malleoli and dorsum of the foot The foot was in a position of slight varus X rays revealed subtalar dislocation with separation of the lateral process of the talus (Stage 3) (Figures 8 and 12) After reduction of the dislocation the nature of the injury was easier to assess

In the last two cases (Figures 11 and 12) the anterior process of the calcaneus acting as a buffer caused a compression fracture of the cuboid bone

The patient was immobilized in a plaster cast for 8 weeks Six months later he still had some pain when walking X rays showed

Figure 12 Fracture of the lateral process of the talus stage 3

Figure 13 Same foot as in Figure 12 after reduction of the dislocation





union of the fracture but severe osteoporosis of the entire region Since then it has proved impossible to get in touch with this patient

In each of these cases the fracture was produced by a fall the patient landing on the injured foot but none of the patients could describe the details of the event

At about the time that we saw Case 3 this type of fracture was reported in a single case by *Haage* (1961) who did not enter into its mechanism and by *Dimon* (1961) who reported 3 cases 2 of which had been overlooked for 6 weeks *Dimon* advanced various theories to explain the fracture mechanism all of which differ from that described above He believed that the most likely cause was a forced pronation *Dimon* referred to *Bonin* (1950) who described this fracture and also felt that it was due to a pronation trauma Previous publications have not described stages in this type of fracture

The conditions which occasion a fracture of this type are presumably rare Like *Dimon* I believe that the fracture may be easily overlooked and that an overlooked fracture may just like other intra articular hind foot fractures result in serious consequences to the mechanical function of the foot

SUMMARY

In the author s opinion a fracture of the lateral process of the talus is due to a supination-dorsal flexion trauma Three cases representing three different stages of this fracture are reported

RESUME

De l'avis de l'auteur une fracture d'une tubérosité du talon est due à un trauma de flexion de supination dorsale Trois cas representant trois differentes phases de cette fracture sont rapportes

ZUSAMMENFASSUNG

Der Verfasser ist der Meinung dass der Bruch des Processus lateralis tali auf ein Trauma mit Supination und Dorsalflexion zurückzufuhren ist Drei Fälle die drei verschiedene Stadien diese Bruches darstellen werden berichtet

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CHANGE OF FORM OF THE FOOT AND THE FOOT SKELETON UPON MOMENTARY WEIGHT BEARING

By

S Carlsoo & H Wetzenstein

Received 15 vi 67

An often discussed question is that which concerns the behaviour of the arch of the foot and of the foot skeleton during weight bearing of the foot The answers to this question which can be found in the literature are by no means uniform Benninghoff states for example in his book on anatomy 1949 that the navicular bone is depressed on weight bearing of the foot by 6 5 mms on average Fick mentions in this respect the figure 8 mms and adds that the bones of the whole foot are depressed but that their mutual positions do not change when the foot bears weight According to the investigations of H Virchow[1] the foot arch prolonged 19 mms within the second ray and 8 mms within the fifth ray upon weight bearing At the same time the foot becomes broader so that the distance between the bases of the first and fifth metatarsals increases by a mean figure of 8 5 mms In a radiological study of the foot s change of form over a short and long period of weight bearing Weitmauer considered that he was able to demonstrate that X rays taken of a weight bearing and a non weight bearing foot were identical or almost identical If any difference existed it consisted in a minor elevation of the foot arch when the foot bore weight At the same time the foot s length became somewhat less This change in shape was explained by saying that when the foot bore weight the short plantar foot muscles were activated together with the posterior tibialis muscle the flexor hallucis longus and the peroneus longus By means of this muscle action the arch of the foot was apparently main

[1] According to G *Hohmann* Fuss und Bein fünfte ergänzte Auflage Verlag J F Bergmann München 1951

tained and even elevated upon weight bearing Electromyographic studies of later years showed however that upon static weight bearing of the foot *e g*, in an upright symmetrical rest position, none of the foot's muscles were in action Static weight bearing of the foot must therefore signify an increased load on the ligamental apparatus of the foot How the ligamental apparatus behaves upon receiving large momentary loads has not previously been investigated

In order to obtain information concerning this and to form an independent view of the change in the normal foot on momentary weight bearing,—since the literature could not provide satisfactory details of this—a radiological and anthropometric study of a series of clinically normal feet was undertaken Moreover the Swedish shoe industry had put the question to the authors of this article of whether and how the form of a healthy foot was changed upon momentary weight bearing *e g*, when trying on shoes The problem was therefore of both anatomical and practical economic interest

MATERIAL AND METHOD

Nineteen students of the Royal Gymnastic Central Institute in Stockholm were examined 10 of these students were male and 9 were girls Their age varied between 19 and 22 years and their body weights between 50 7 and 96 8 kgs None of those taking part in the tests had any foot trouble nor had anyone experienced it previously Clinically and orthopaedically these individuals exhibited certain variations in the shape of the foot but these were of such slight degree that the test group could be regarded as forming a normal series

X rays were taken of the left foot as the test individual stood upright on both feet As underlying support for the left foot a 2 cms thick plate of plastic was employed which was fixed horizontally above a force plate (Figure 1 b) (*Carlsöö* 1962) Between the plastic plate and the force plate there was a narrow gap large enough to accommodate an X ray plate Two metal wires were inserted into the plastic plate at right angles to each other the one longitudinally and the other transversely so that their point of intersection lay approximately at the centre point of the plastic plate The metal wires formed a coordinate system Three X ray tubes were firmly directed towards this coordinate system Longitudinally along one side of the plastic plate and transversely along one short side there were placed two casette holders for lateral (1 d) respectively axial (1 c) radiographs In the former cases the rays passed in a latero medial direction and in the latter case in an anterior posterior direction On the film lying beneath the plastic plate frontal pictures were taken A lead indicator about 2 × 2 mms in size was fixed to the skin above the tuberosity of the navicular bone The foot was positioned on the plastic plate in the angle formed by the two upright casettes and with the heel and the medial aspect of the foot in contact with the casettes (Figure 1) The longitudinal axis of the foot then lay approximately directly above the longitudinal wire in the

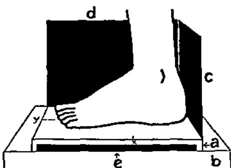


Figure 1 Diagram of foot and position of X ray plates a) plastic plate sup porting foot b) force plate c) d) e) X ray plates

plastic plate and the tuberosity of the navicular bone was in the same frontal plane as the transverse wire The focus film distance was 100 cms for all three projections In the lateral projection the central ray passed horizontally and at right angles to the film 6 cms above the supporting surface of the foot and on a plane with the transverse wire in the plastic plate i e through or very close to the lead indicator above the tuberosity of the navicular bone The central rays of the other two X ray tubes were ranged on a plane with the longitudinal wire in the plastic plate and thus with the longitudinal axis of the foot. Both tubes were placed in front of the test individual The focus on the X ray tube with which the axial picture was taken lay 7 cms higher than the intersection point between central ray and film It was calculated that the ray would pass through the talo crural joint and thus form an angle of approx 4 with the horizontal plane through the joint. The axial pictures were not however utilised in drawing up the results given below The central ray of the frontal picture passed a point on the longitudinal wire in the plastic 9 cms before the point of intersection between the two wires and making a forward open angle with the horizontal plane of 85

As a support for the right foot a wooden bench was placed about 30 cms from the force plate and level with the plastic plate on the force plate

That part of the weight of the body which was borne by the left foot and thus by the force plate was recorded on a Honeywell Visicorder In quick succession three pictures were taken one by each of the X ray machines when the test indi viduals stood in the following three postions a total therefore of nine pictures. The first three pictures were taken in a *symmetrical* standing rest position with the body weight evenly distributed over the right and left foot. With this foot position maintained almost the whole of the body weight was then transferred to the right foot by means of a careful inclination of the body to the right This position is called below asymmetrical rest position A and the left foot is regarded as *unloaded* Afterwards body weight is transferred in a similar way to the left foot and this position is called asymmetri al rest position B and the left foot is designated *max loaded*

In order to obtain a preliminary understanding of the changes in position of the bones of the foot with the various loads the X rays were examined in a stereocom parator Two pictures were placed in this apparatus the one picture of an unloaded foot and the other of the same foot max loaded or symmetrically loaded Even if the identification of various skeletal points is not completely exact this procedure

is nevertheless far superior to a two dimensional reading (*Hallert* 1953) The points and contours which were utilised as measuring points are shown in Table 1

Table 1 Measuring points on radiographs of the foot and the distal end of the leg

Lateral pictures

1 Furthest anterior point of tibia
2 Furthest posterior point of tibia
3 The most proximal point of the trochlea of the talus
4 Proximal anterior tip of the head of the talus
5 Furthest anterior point of the head of the talus
6 Distal tip of fibula
7 Furthest posterior point of calcaneus
8 Furthest plantar point of calcaneus
9 Furthest anterior point of calcaneus
10 Proximal dorsal point of navicular bone
11 The dorsal proximal tip in the joint cavity in the carpo metacarpal joints
12 The dorsal distal tip in the joint-cavity in the carpo metacarpal joints.
13 Furthest distal point of the cuboid
14 Furthest plantar point of the base of the 5th metatarsal bone
15 Furthest plantar point of the head of the 5th metatarsal bone
16 Furthest dorsal point of the head of the 1st metatarsal bone
17 Furthest anterior point of the head of the 1st metatarsal bone
18 Furthest plantar point of the head of the 1st metatarsal bone

Frontal pictures

1 Furthest medial point of the head of the 1st metatarsal bone
2 Furthest medial point of the head of the 2nd metatarsal bone
3 Furthest medial point of the head of the 3rd metatarsal bone
4 Furthest medial point of the head of the 4th metatarsal bone
5 Furthest medial point of the head of the 5th metatarsal bone
6 Furthest lateral point of the base of the 1st metatarsal bone
7 Furthest lateral point of the base of the 2nd metatarsal bone
8 Furthest lateral point of the base of the 3rd metatarsal bone
9 Furthest lateral point of the base of the 4th metatarsal bone
10 Furthest lateral point of the base of the 5th metatarsal bone
11 Furthest medial point of the cuneiform bone
12 Furthest medial point of the navicular bone
13 Furthest lateral point of the cuboid
14 Furthest distal point of the head of the talus
15 *Furthest distal point of the calcaneus*

The measurements in the stereocomparator showed that the changes in position of the measuring points in the lateral pictures were considerable Differences of up to 5 mms often occurred On the other hand the differences in the frontal pictures were small These conditions show that as was expected the changes of position occur principally in a craniocaudal direction A completely satisfactory measurement

Figure 2 Foot measuring instrument by Haraldson with force plates mounted type Wet enstein



of the size of these craniocaudal displacements as well as sagittal displacements cannot be carried out however Certain rotatory movements may arise in weight bearing of the foot which make difficult and indeed impossible an identification of the measuring points which is free from objection Nevertheless a precisely executed measurement of the lateral pictures can produce values which are sufficiently reliable to be used as a basis for an evaluation of the change in form of the foot skeleton in those individuals examined who were given the varying loads

In measurements of radiographs taken on two different occasions in one case on three different occasions and in one case on five different occasions—the values were almost identical. No variations in the readings occurred of such magnitude that they could affect the conclusions to be drawn from the investigation if the distal tip of the fibula is excepted i e point 6 on the lateral pictures These variations are due to changes in the position of the ankle joint

In the measurements of the lateral pictures an orthogonal coordinatograph was used of the type Simonson and Klintmalm The coordinate system was placed over the radiograph so that its y axis passed through the dorsal top of the lead indicator above the tuberosity of the navicular bone and its x axis coincided with the weight bearing plan of the foot (more precisely the longitudinal wire inserted into the plastic plate)

The external shape of the foot and the contour changes were measured by Haraldson s foot measuring instrument (SFI publication 1954) under the same weight bearing conditions as in the radiological studies i e with a symmetrical and maximall loaded foot and also with an unloaded foot Two force plates were used to record the foot loading one for the heel and one for the fore foot (Figure 2) (*Wet enstein* 1964 *Carlsoō* 1964) In this way it could be checked that the percent age distribution of weight on the heel and fore foot remained unchanged when the total loading was changed. Of the measurements taken with Haraldson s measuring instrument foot length ball breadth and the circumference of the ball were utilised By ball breadth is meant the external distance between the medial border of the head of the 1st metatarsal bone and the lateral border of the head of the 5th metatarsal bone The circumference of the ball was measured level with these two measuring points The accuracy of the method was tested by two investigators with four double measurements The difference was never more than 1 mm.

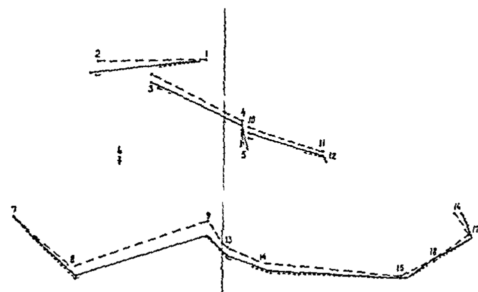


Figure 3 Position of measuring points with varying loads of the foot

— — — — non loaded foot
———— symmetrically loaded foot
– – – – – – maximally loaded foot

RESULTS AND DISCUSSION

Figure 3 shows the internal position of the measuring points and their position in relationship to the coordinate system of the orthogonal coordinatograph in one case with the three varying loads The corresponding tracings of the other 18 cases will be found in Figure 4 In order to clarify the displacement of the measuring points and so the change in form of the skeleton the measuring points were connected by straight lines Link lines 1–2 show changes in position of the distal end of the tibia Link lines 3–4–5 refer to the talus Link line 10–11–12 represents the dorsum of the foot at its medial border The link line 7–8–9 concerns the calcaneus and 13–14–15 the cuboid and metatarsal V and 16–17–18 indicates the head of metatarsal I

The straight line which connects measuring point 7 with measuring point 17 is called here foot length and the distance at right angles from point 3 to the straight line which passes through points 8 and 15 is called foot height As Figures 3 and 4 show in one case the foot length increased by 3 mms (case 6) while no change in length could be measured in the other cases The changes in foot height were also

so insignificant—a mean of 0 15 mms—that one cannot speak of any true changes in the form of the foot skeleton during weight bearing of the foot

The anthropometric measurements showed no significant difference in either foot length or ball breadth in differing loadings of the foot The average difference did not extend to 1 mm On the other hand there was a systematic difference in the circumstance of the ball upon various loads with an average difference of + 4 9 mms between unloaded and maximally loaded foot and + 2 5 mms between unloaded and symmetrically loaded foot Foot length and ball breadth are principally skeletal measurements while the circumstance of the ball is a soft tissue measurement These anthropometric measurements coincide fully with the radiological *i e* the foot skeleton does not undergo any demonstrable changes in position in the sagittal and transverse direction when the foot bears weight The increase in width within the region of the ball of the foot *i e* within the region of the metatarsal heads which arises on weight bearing of the foot seems therefore to be a soft tissue change When the foot bears weight the subcutaneous tissue is pressed together and displacements in a medial and lateral direction occur and produce stretching of the tissues so that measurable increases in volume arise

Since the muscles of the foot do not seem to be in action on static weight bearing in a symmetrical standing rest position (*Basmajian & Bentzon* 1954 and others) then this must mean that the ligamental mechanism and plantar aponeurosis play a decisive role in the stability of the foot skeleton even if the passive resistance of the muscles to stretching and the internal positional relationships of the skeletal parts may contribute to stability The fact that the foot skeleton is considerably more depressed in passing from unloaded to symmetrically loaded foot than from symmetrically loaded to maximally loaded foot is in full accordance with the rheological qualities of the connective tissue even though the increase in load is the same on the whole in both cases Thus studies of stress strain behaviour in specimens of ligament tendon and other connective tissue structures show that the degree of stretching is not proportional to the load but decreases considerably with increased load Therefore the passive forces in the material studied can fix the different joints of the foot so powerfully that when the foot bears weight no true depression of the foot s longitudinal arch takes place

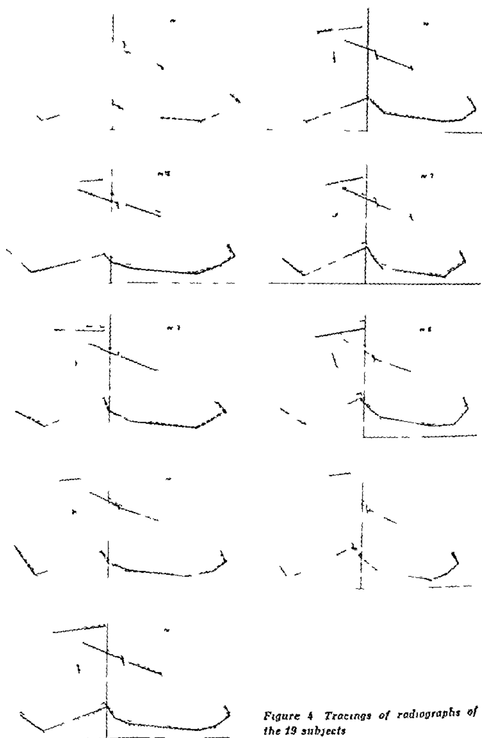
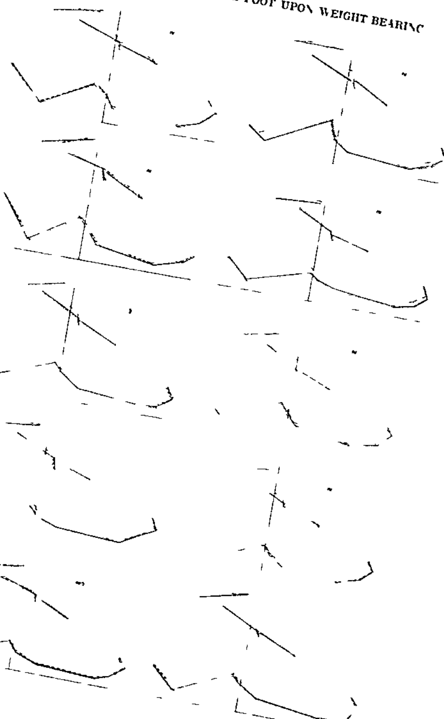


Figure 4 Tracings of radiographs of the 19 subjects



SUMMARY

A radiological and anthropometric investigation into changes of form of the foot and the foot skeleton on weight bearing was carried out on 19 students Clinically and orthopedically the series is considered to be *normal series No changes in the form of the foot skeleton* could be demonstrated The external changes in form of the foot which arise when the foot bears weight are due to alterations and displacements of soft tissues The active and passive supporting mechanism of the foot is discussed

RESUME

Un examen radiologique et anthropométrique du pied et des modifications du squelette du pied dans des épreuves de charge a été effectué chez 19 étudiants Au point de vue orthopédique clinique les sujets doivent être considérés comme un matériel normal *Il n a pas été* possible de constater une déformation du squelette du pied Le changement extérieur de la forme du pied qui apparait sous la charge est du a une déformation et a un déplacement des tissus mous Il est discuté de l appareil de choc actif et passif du pied

ZUSAMMENFASSUNG

Eine röntgenologische und antropometrische Untersuchung der Formveränderung des Fusses und Fussskelettes bei Belastung des Fusses wurde an 19 Studenten vorgenommen Klinisch orthopedisch ist das Material als ein Normalmaterial anzusehen Irgendwelche Veränderungen des Fussskelettes konnte man nicht nachweisen Die beobachteten äusseren Formveränderungen des Fusses bei der Belastung beruhen auf Deformierung und Verschiebung der Weichteile Die aktiven und passiven Stützapparate des Fusses werden besprochen

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From the Orthopaedic Hospital Aarhus Denmark
(Head Professor Eivind Thomasen M D)

CALCANEO NAVICULAR COALITION

Late Results of Resection

By

Erik Andreasen

Received 2.XII 67

INTRODUCTION

Up to 1920 calcaneo navicular coalition was considered an unimportant anatomical variant *Slomann* (1921) was the first to demonstrate a possible relationship between coalition and painful fixed hindfoot He suggested treating the condition by resection, but feared further development of the pronation deformity found in all his cases

Badgley (1927) and *Benkon* (1928, 1932) reported the first results of resection

Since that time numerous authors including *Hayd* (1949) *Webster & Roberts* (1951) *Rössler* (1956) *Hohmann* (1961) and *Mitchell & Gibson* (1967) have expressed the view that resection alone or combined with interposition of muscular tissue or other material was applicable for children provided that the shape of the foot was well preserved and that X rays did not reveal any signs of osteoarthritis The operation is followed by a period of immobilization After treatment by supports in ordinary shoes

In adults and adolescents who show radiological signs of abnormal pressure especially in the talonavicular joint there is all authors agree indication for arthrodesis either talo navicular (*Bentzon* 1928) or of further joints usually in the form of triple arthrodesis (*Badgley* 1927 *Rendu* 1928 *Seddon* 1933 *Harris & Beath* 1948 *Ernsting* 1956 *Sour* 1959 and *Heikel* 1962) Supplementary tendon transplantation is used by *Niederecker* (1955) among others

The adherents of arthrodesis were not impressed by the results of resection but only *Mitchell & Gibson* (1967) have submitted a resected material followed for many years From their analysis it is apparent

that by simple resection of the bar a satisfactory result was obtained in 76 per cent of 48 treated patients The follow up period ranged from 4 to 13 years The most favourable results were obtained in children younger than 14 years if they did not have deformity of the foot or signs of adaptive joint changes at the time of operation As regards the mobility in the subtalar joint and the incidence of recurrence of the coalition their results are in keeping with those which will be reported below

MATERIAL AND METHODS

The object of the present study was to assess the value of the method by a follow up study on resected cases of calcaneo navicular coalition

Operative Method

Bentzon s technique (1928 1932) dorsolateral incision over the coalition detachment of the extensor digitorum brevis muscle from its origin Resection of the coalition close to the navicular bone and calcaneus interposition of the detached muscle belly into the defect left by the resection. The muscle is kept *in situ* by a pull-out wire through the sole Plaster cast usually for 3 weeks. After treatment by supports in the shoes

During the period 1936 to 1948 31 resections on a total of 25 patients (13 males and 12 females) were carried out in the Orthopaedic Hospital Aarhus The right foot was treated in 13 cases the left in 18 Six patients had the operation on both feet.

Six patients (2 males and 4 females) continued to have such painful feet that triple arthrodesis was performed secondarily in all cases on one side only even in the 3 patients who had bilateral primary operations Four of these patients had the arthrodesis within 2 years of the resection

The resection series comprises 22 patients (13 males and 9 females) having a total of 25 operations not followed by secondary arthrodesis

The follow up study was carried out in the years 1958 to 1960 One patient who is a miner abroad was not examined but reported that he had no complaints from the foot also not during heavy work. All the others were examined by the author The follow up period ranged from 10 to 22 years. In 20 cases the follow up examination was done more than 15 years after the resection Table 1 gives a survey of the material by side resected and by sex

At the time of operation the patients were 11–23 years of age Twenty had the operation before the age of 15 and only one was over 20 Half the feet had been painful for more than one year prior to the operation The factors which elicited this pain were unknown in 25 cases A possible occupational cause was stated by 5 while only one considered a mild injury to be responsible for the symptoms

All presented themselves because of pain and/or fatigue in the foot and leg No one adduced spontaneous complaints concerning the shape of the foot, and only one patient had noticed restriction of subtalar mobility In 8 cases the complaints were so severe that the working ability was appreciably reduced

According to the case records physical examination showed the foot to be in

neutral position or in slight pronation in 22 cases severe pronation in 8 and with slight cavus deformity in one Subtalar mobility was stated to be normal in one case distinctly reduced in 8 and abolished in 2?

Table 1 Cases of calcaneo navicular coalition treated by resection

	Males		Females		Total
	Right	Left	Right	Left	
Resection after examined	4	8	6	6	?4
Primary resection secondary triple arthrodesis after examined	2	0	1	3	6
Resection not after examined	0	1	0	0	1
	6	9	7	9	31

Postoperatively one patient went into mild shock and one developed negligible infection in the wound while all other operations were uncomplicated

After the plaster cast removed about 3 weeks after the operation all the patients used *supports in the shoes at least for a few months*

The period off work after the operation was in most cases only weeks to a few months However 2 patients were off work for more than 6 months because of persisting pain in the foot Three males and one female had to change their occupation because of the foot. This change of occupation became permanent only in the case of 2 of the males

Prior to the operation all the patients were X rayed with special regard to calcaneo navicular coalition (*Slomann* 1926) In 15 cases exposures were made also in the dorsoplantar and lateral views Signs of osteoarthritis in the form of marginal exostoses narrowing of the joint space or subchondral sclerosis were demonstrated in 4 cases in the talo navicular joint and in one case also in the subtalar joints Six feet exhibited more or less marked halisteresis of the areas adjacent to the coalition while only one case had diffuse halisteresis of the entire foot

The bar presented itself in 4 cases as a solid bridge between the navicular bone and calcaneus All others were divided by a distinct gap in half the cases in the middle of the bar Among the other half an equal number had the gap closer to the calcaneus and closer to the navicular bone In one foot there was a tiny secondary os calcis in the gap

FOLLOW UP

Data concerning the history and social factors were recorded at the time of the physical examination of the lower limbs X rays were *obtained of the ankle joint and foot including a special* coalition projection and the talo crural articulation was tested for instability

The *resection material* comprises 24 feet

Nine patients (9 operated feet) reported pain in the tarsus In 7 the

pain was slight and negligible and only 2 patients had more severe pain Eight complained of a tendency to fatigue in the operated leg One patient found the subtalar mobility to be inconveniently restricted When asked about the appearance of the foot 4 patients complained that it was too flat and three—all women—had problems in getting ready made shoes that would fit them

Five patients had done their military service after the operation but 2 of them had done only light service

All the patients were working 21 under conditions where they stood or walked a lot 8 often on rough ground All considered their earning capacity to be normal but 2 men felt that the foot was somewhat annoying in their work

A total of 13 patients stated that they had no complaints at all on account of the foot no matter what they did 9 felt discomfort from the foot upon special unaccustomed efforts while 2 patients were annoyed by pain in the foot

At follow up the patients ranged in age from 24 to 39 years

In 19 unilaterally operated cases there was atrophy of the lower leg amounting to 1 and 2 cm in 4 cases and to more than 2 cm in 2 The shape of the foot was normal or there was slight pronation in 19 cases considerable pronation in 5

Movement in the ankle joint judged by the axis through the lower leg and a plane through the sole varied from 35 to 65 average 42 This must be considered normal as tested by this technique Subtalar mobility determined as an estimated percentage of the normal excursions was found to be abolished in 4 reduced in 9 and normal in 11 cases This was a distinct improvement compared with the preoperative condition

None of the patients walked with a limp when wearing shoes Only one foot proved tender at the site of the subtalar joints

All 24 feet and ankle joints were X rayed at follow up The ankle joints showed osteoarthritis in the form of slight marginal exostoses on the anterior edge of the tibia in 2 cases The ankle joints were examined for instability by manual supination and pronation pressure upon the hindfoot in relation to the lower leg The angle between the joint surfaces of the tibia and talus was measured Total instability is stated as the sum of the supination and pronation tilting of the talus in relation to the tibia In 17 ankle joints there was instability of 1 or less in 3 ankle joints of 2 in 2 ankle joints of 3 while 1 ankle joint tilted 4 and 1 tilted 5 This distribution cannot be considered abnor

neutral position or in slight pronation in 22 cases severe pronation in 8 and with slight cavus deformity in one Subtalar mobility was stated to be normal in one case distinctly reduced in 8 and abolished in 22

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Nine patients (9 operated feet) reported pain in the tarsus In 7 the

tion de la mobilite sub-talaire Neanmoins les radiographies ont montre le retour d une coalition dans les deux tiers des pieds et dans 23 sur 24 une osteoarthrite determinee dans l articulation du tarse dite Chopart meme avant que les malades aient atteint l age de 40 ans

Dans ces conditions j ai l impression que la resection ne peut pas etre recommandee puisque dans la plupart des cas elle est suivie d osteoarthrite Une triple arthrodese doit etre consideree comme etant plus sure

ZUSAMMENFASSUNG

Nach einer Zeitspanne von 10–22 Jahren wurden 31 Füsse die ursprunglich mittels Resektion einer Coalitio calcaneonavicularis behandelt worden waren nachuntersucht

In 6 Fallen war eine Tripelarthrodese sekundär ausgefuhrt worden Die Ergebnisse der Resektion waren subjektiv in 13 Fallen gut während 9 Patienten noch leichtere Beschwerden und 2 starke Schmerzen hatten Ein Patient wurde nicht gesehen berichtete aber dass er keinerlei Beschwerden hatte

Die objektive Untersuchung zeigte eine gut erhaltene Form des Fusses gute Beweglichkeit im Knochelgelenk und oft Wiederherstellung der subtalaren Beweglichkeit Rontgenbilder zeigten jedoch ein Wiederauftreten der Coalitio bei zwei Dritteln der Füsse und 23 von 24 Fussen wiesen eine ausgesprochene Osteoarthitis besonders des Chopart Gelenkes auf selbst ehe die Patienten das Alter von 40 Jahren erreicht hatten

Deshalb meine ich dass die Resektion nicht anzubefehlen ist da sie in den meisten Fallen von einer Osteoathritis gefolgt wird Tripelarthrodese muss als das sichere Vorgehen angesehen werden

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RELATIONS BETWEEN FEMUR DENSITY AND STRONTIUM 85 UPTAKE IN BIPEDAL RATS

By

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Received 2 viii 67

The rate of entry of isotopes of calcium and strontium into bone is referred to as the accretion rate and is generally held to be a good parameter of bone formation rate in animals and humans (*Bauer* 1954 *Wendeberg* 1961 *Dymling* 1964) We have found (*Nilsson & Saville* 1967) that when rats sustain a fracture of the tibia the ipsilateral femur does not grow as fast as the contralateral femur The twenty four hour uptake of strontium measured as per cent of dose per unit ash in the smaller femur on the fractured side is greater than that in the larger femur on the uninjured side but the same as that in a femur of the same volume and density from a smaller rat This suggests that bone density rather than bone formation governs the uptake of radiostrontium under these conditions To test this point further we have altered the relations between body weight and bone density by raising bipedal rats which have larger denser and stronger femora than normal rats of the same weight (*Saville & Smith* 1966 *Smith & Saville* 1966)

MATERIAL AND METHODS

In thirty four male Sprague Dawley rats of the Charles River strain bipedalism was accomplished shortly after birth according to the method of *Saville & Smith* (1966) The animals were raised after weaning on a commercial rat diet They were killed at pre determined weights between 50 and 500 g Fifty six control rats of the same sex and strain fed the same diet were killed at approximately the same weight range Twenty four hours before sacrifice each animal was injected subcutaneously with about three microcuries of strontium 85 The left femur was removed from each animal cleaned of soft tissue and weighed suspended from a fine copper wire in air and in water at 4 C. The volume was determined according to Archimedes Principle The bones were ashed for forty eight hours at 600 C. the ash was

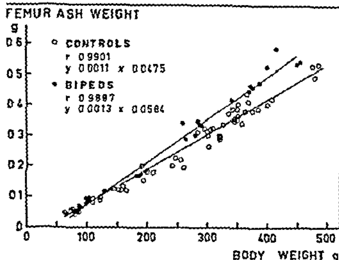


Figure 1 Femur ash weight is plotted as a function of body weight Regressions are calculated by the method of least squares There is a significant slope difference ($P < 0\ 001$)

weighed and transferred to test tubes where the radioactivity was measured in a well scintillation counter to a precision of 1 per cent By comparing the counting rate of the samples to that of a known standard the activity was calculated and expressed as per cent of the injected dose Regressions were calculated by the method of least squares and were compared one with another by analysis of co variance

RESULTS

The ash weight of the femur was a linear function of body weight both in the controls and in the bipeds but at any given body weight the bipeds had significantly more ash ($P < 0\ 001$) (Figure 1) The volume of the femora also was a linear function of body weight in both groups but the bipeds had significantly greater volume at any given body weight ($P < 0\ 001$) (Figure 2) The density of the femora expressed as grams of ash per cubic centimeter of bone was a linear function of body weight in both groups but the bipeds had significantly greater bone density than the controls ($P < 0\ 001$) (Figure 3) The ash weight of the femora approximated a linear function of the femur volume in both bipeds and controls and at any given femur volume the ash weight was not significantly different in the two groups of animals (Figure 4) The specific activity of Strontium 85 was a negative exponential function of bone density and at any given bone density the specific activity

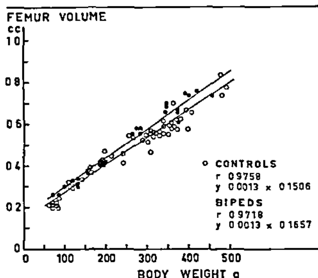


Figure 2 Femur volume is plotted as a function of body weight Regressions are calculated by the method of least squares There is a significant difference in adjusted means ($P < 0.001$)

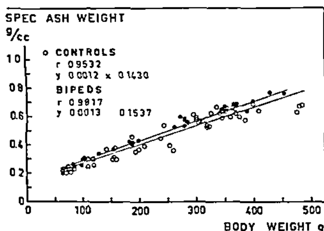


Figure 3 Ash per cc of femur is plotted as a function of body weight Regressions are calculated by the method of least squares Analysis of covariance shows a significant difference in adjusted means ($P < 0.001$)

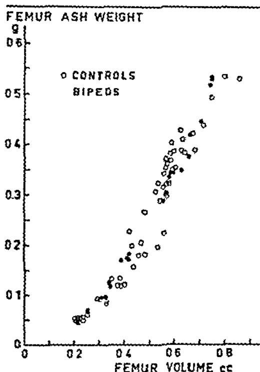


Figure 4 The ash content of the femora is plotted as a function of femur volume At any given femur volume there is no significant difference in ash content in the two groups

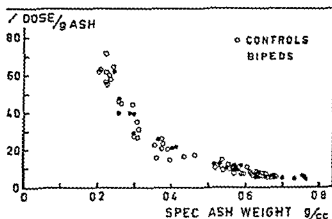


Figure 5 Specific activity of the femur is plotted as a function of femur specific ash weight At any given specific ash weight there is no difference in specific activity in the two groups

was identical in both groups (Figure 5). In short, bipedal femora are larger than controls of the same weight but they have just the right amount of Strontium 85 for bones of their density.

DISCUSSION

Bipedal rats have larger, denser and stronger femora for their body weight than do controls. We have succeeded in disturbing the relation between body weight and femur growth in these animals. The changes thus introduced, however, did not interfere with the relationship of size, density and uptake of Strontium 85. This supports our previous observation that bone density or a physical property of bone related to density is an important factor influencing the uptake of mineral tracer in the rat femur.

SUMMARY

The volume, the mineral content and the twenty four hour uptake of Strontium-85 were measured in the femora of bipedal and quadripedal rats. The relationships of ash content to volume and of uptake of Strontium-85 to density were not influenced by the changes of femur growth introduced by bipedalism.

RESUME

Le volume, la teneur en mineral et l'absorption pendant 24 heures de Strontium 85 ont été mesurés en les deux femurs sur des rats bipedes et quadripedes. Le rapport entre la teneur en cendres et le volume et entre l'absorption de Strontium 85 et la densite ne sont pas influences par les modifications de la croissance du femur introduites par le bipédalisme.

ZUSAMMENFASSUNG

Das Volumen, der Mineralgehalt und die vierundzwanzigsundige Aufnahme von Strontium 85 wurden in den Femora von zwei- und vierfüssigen Ratten gemessen. Das Verhaltnis von Aschengehalt zu Volumen und von Strontium 85 Aufnahme zu Dichtigkeit wurde durch die Veränderungen des Femurwachstums, die durch Zweifüssigkeit hervorgerufen worden war, nicht beeinflusst.

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DIAGNOSTIC DIFFICULTIES IN LOWER CERVICAL SPINE DISLOCATIONS

By

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INTRODUCTION

The object of this paper is to point out the risk of overlooking fractures and dislocations in the lower part of the cervical spine and to describe a reliable diagnostic technique

Ebbehøj, in 1942 said that there are mainly three reasons why fractures of the spine are overlooked (1) The trauma has not been considered sufficient to cause a fracture of the spine (2) The primary symptoms have not been so violent as to suggest to the doctor a possibility of fracture (3) The X rays taken have been insufficient not visualizing the injury This third reason may be avoided when bearing in mind that A positive X ray finding means much at times everything in the diagnosis a negative finding means something but a negative finding in a poor X ray exposure means nothing at all

Others (*Braakman & Vinken* 1967 *Norton* 1962) have pointed out that in an X ray examination of the cervical spine it must be secured that all the vertebrae are visualized since not uncommonly a dislocation of C 6 on C 7 or of C 7 on T 1 will be overlooked because this region is superimposed by the shoulders in the lateral view

It must be admitted that by the current standard exposures of the cervical spine in patients with acute injuries it is not always possible to reveal dislocations between the lower cervical vertebrae These diagnostic difficulties are illustrated by the following two case histories

CASE REPORTS

(B 1476 1) A man aged 50 was admitted to a surgical department after having fallen 5 metres from a roof hitting the back of his neck against the ground He was complaining of severe pain at the back of the neck. X rays of the cervical spine



Figure 1 Lateral view taken in the recumbent position at the primary examination of Case 1

Figure 2 Anteroposterior view taken in the recumbent position at the primary examination of Case 1

Figure 3 Lateral view taken of Case 1 in the erect position 11 weeks later

revealed a fracture of the spinous process of C 2 Objective examination of the limbs did not show any neurological abnormalities After 11 days in hospital he had out patient massage treatment of the back of the neck but as this aggravated the pain he stopped attending Owing to persistent pain and to the appearance of paraesthesiae and a feeling of weakness in the right hand he was referred to the Orthopaedic Hospital—6 weeks after the accident Here the findings were a severe restriction of movement in the cervical spine and hypalgesia radially on the right hand but no other neurological abnormalities New X rays of the cervical spine in 4 projections and special views of the uppermost vertebrae again showed normal appearances apart from a blurred fracture of the spinous process of C 2 The lateral view as in the primary exposures showed the appearances only down to C 6 because of the superimposed shoulder (Figure 1) In the anteroposterior and oblique views the structures of the lowermost cervical vertebrae were somewhat blurred but this was interpreted as spondylotic changes To immobilize the neck a plastic collar was fitted At follow up 11 weeks after the accident the pain has disappeared Objective examination still showed mild hypalgesia dorsally at the root of the right index finger and now a striking prominence of the spinous process of C 7 was noted Therefore further X rays were obtained In the lateral view it was now possible to visualize also C 7 and this disclosed total dislocation between C 6 and C 7 with displacement which measured four fifths of the width of the vertebral body and an angulation of 40 (Figure 3) The patient was now admitted and treated with Crutchfield skull traction for 2 months Thereby the angulation was abolished and gradually the two vertebrae fused anteriorly After treatment by plaster collar and later by plastic collar 9 months after the accident the site was stable there was restricted mobility in the neck but no neurological abnormality and the patient went back to work as a butcher

(B 148 871) A man aged 36 was admitted to a surgical department with symptoms and signs of mild concussion after a motor accident On the third day he complained



Figure 4 Lateral view taken in the recumbent position at the primary examination of Case 2

Figure 5 Lateral view taken 4 months later of Case 2 in the erect position

Figure 6 Oblique view taken 4 months later of Case 2 in the erect position

of pain at the back of the neck and in the right shoulder so that the cervical spine was X rayed The films showed no abnormalities (Figure 4) He was discharged on the 15th day The pain persisted and the patient developed paraesthesiae of the right index and long fingers and a feeling of weakness in the right arm As these symptoms continued he was referred to the Orthopaedic Hospital 4 months after the accident No neurological abnormalities were found but there was considerable limitation of movement in the cervical spine and a striking prominence of the spinous process of C 7 Renewed X ray examination now gave a good survey also in the lateral projection revealing a dislocation between C 6 and C 7 with displacement of almost half the width of the vertebral body and an angulation of 25 (Figure 5) Oblique views showed that the dislocation was only left sided (Figure 6) The vertebrae had already fused by a bony bridge anteriorly and the site was stable so treatment was not felt to be indicated However the patient was kept off work for another few months

DISCUSSION

These two case histories constitute an alarming memento that even severe injuries to the cervical spine may be overlooked because of lacking perspicuity in the current X ray views As it is important to treat dislocations of the cervical spine attempts must be made to diagnose them during the acute phase For this reason the value of the X ray examinations will be discussed First mention will be made of the incidence causes and lesion mechanism in dislocations and fractures

of the cervical spine whereas the therapeutic problems will not be discussed

Injuries to the spine are very common but only a small percentage affect the cervical part From 1947–1951 *Trojaborg & Bryndum* (1959) found that among 1035 spinal injuries only 7 per cent were cervical 2½ per cent of the injuries were pure dislocations and these occurred only in the cervical spine Cervical spine lesions are most commonly localized in the area between C 4 and C 7 In a study of 77 forward dislocations in the area C 3–T 1 *Ramadier & Bombart* (1967) found 36 to be localized between C 6 C 7 and T 1

In respect to the aetiology the greatly increasing incidence in connection with motor accidents must be mentioned *Brooks* (1933) found that 12 per cent were due to motor accidents and 50 per cent to falls For the period 1946–1955 *Durbin* (1957) found traffic accidents to be responsible in almost 30 per cent falls in roughly 30 per cent and diving into shallow water in 20 per cent During the period 1950–1959 *Norton* (1962) found 70 per cent to be due motor accidents only 15 per cent to falls and 10 per cent to diving into shallow water

As patients involved in traffic accidents often have multiple injuries several of which cause more striking symptoms than does a mild affection of the cervical roots a cervical injury is particularly apt to be overlooked in these cases unless the patient is examined for this very purpose

In an analysis of the detailed mechanism of lesion to the cervical spine *Holdsworth* (1963) found that a pure flexion trauma most often results in a wedge shaped fracture of the vertebral body without an attendant injury to the interspinous and supraspinous ligaments and that accordingly these fractures usually do not cause instability Flexion rotation traumas cause primary rupture of the posterior ligaments and secondarily perhaps dislocation occasionally complicated by fracture When the posterior ligaments have ruptured the site is unstable *Holdsworth* therefore pointed out the importance of a clinical examination for injury to the posterior ligaments and comparison with good X rays *Durbin* (1957) too mentioned the importance of the posterior ligaments to the stability In order to demonstrate injuries to these ligaments he recommended lateral X rays in flexion with caution and with the assistance of a doctor

In experiments on cadavers *Beatson* (1963) found that—to produce dislocation of both articular facets—the interspinous ligament both joint capsules the posterior longitudinal ligament as well as the an

nulus fibrosus had to be destroyed He also found that displacement of less than half the width of the vertebral body was invariably connected with unilateral dislocation and that a displacement of more than half the width of the vertebral body was tantamount to bilateral dislocation From his study it may be deduced that from the lateral X ray views alone it can be decided whether a unilateral or bilateral dislocation is present while oblique views are required to disclose which side is dislocated in unilateral cases

It is extremely important to differentiate between these two degrees of dislocation as soon as possible as the risk of a severe perhaps irreversible cord or root damage is far greater in bilateral than in unilateral cases (*Braakman & Vinken* 1967) It is by no means an invariable rule for a cervical spine injury to cause neurological symptoms this occurs in only about half the cases Therefore the remaining large percentage will risk neurological damage if the spinal lesion is not diagnosed and treated

The ordinary X ray examination of the cervical spine includes only anteroposterior and lateral views In a cooperative patient in the erect position all the cervical vertebrae may be visualized in these views If the patient is X rayed in the recumbent position it is considerably more difficult to prevent superimposition by the shoulders upon the lower cervical vertebrae in the lateral exposure (Figure 7) If the patient is the victim of an accident or in pain the difficulty is increased If furthermore there is damage to the cervical spine the patient will inevitably keep the muscles of the region so fixed that the shoulders become superimposed upon the area distal to C 6 (Figures 1 and 4) This has also been demonstrated by *Towne* (1933) in a patient with an overlooked dislocation of C 6 on C 7 The AP view is of no particular value in disclosing a possible dislocation It is true that in the case of unilateral dislocation there may be a usually very slight lateral displacement of the shadow of the spinous process of the forward dislocated vertebra but this does not apply in the case of bilateral dislocation (Figure 2) Oblique views may be of value in revealing a dislocation but it is rather difficult to assess the lower vertebrae in this projection and the exposures require quite some manipulation with the patient

Therefore the lateral view is decisive in the acute situation but it has its weakness in respect to the lowermost vertebrae Only *Braakman & Vinken* (1967) have mentioned tomography as the last resort in making a diagnosis of unilateral dislocation of C 7 on T 1 However as



Figure 7 Lateral view taken in the neutral recumbent position of a healthy man with hefty shoulders Note that only the 5 uppermost cervical vertebrae are visible

Figure 8 Example of lateral tomography of C 5 C 6 C 7 and T 1 Same person as shown in Figure 7

it is important not to move an injured patient more than absolutely necessary it seems to the present author more advisable to supplement the examination immediately by a couple of tomographic views of the lowermost cervical vertebrae in the sagittal plane if the conventional laterals are not sufficiently informative (Figure 8)

CONCLUSIONS

(1) Dislocations and fractures of the cervical spine are increasing in frequency with the increasing number of traffic accidents
(2) The symptoms and signs of these injuries are often slight in relation to those of other injuries that may co exist and there need not primarily be neurological signs
(3) Even total dislocations between the lowermost cervical vertebrae may be overlooked because of the difficulties of radiological survey in this region in the sagittal plane
(4) Therefore the current projections must be supplemented by a couple of lateral tomographic exposure in the event of lacking perspicuity
(5) Lateral views during flexion must be obtained if there is a sus

picion of injury to the posterior ligaments as such a lesion causes instability between the vertebrae concerned

SUMMARY

On the basis of two cases in which dislocations of C 6 on C 7 had been overlooked during the first stay in hospital the author reviews the incidence causes and mechanism of injuries to the cervical spine The radiographic possibilities of diagnosing dislocations between the lower most cervical vertebrae are discussed considering that the shoulders are superimposed upon this region in ordinary laterals taken in the recumbent position especially of an injured patient who fixes the muscles in the region of the neck It is recommended to use tomo graphic lateral views to secure the diagnosis immediately at the first examination

RESUME

Sur la base de deux observations ou une dislocation entre les vertebres cervicales 6 et 7 avait passe inaperçue lors de la premiere hospitali sation il est etudie la frequence les causes et le mecanisme des lesions de la colonne cervicale Il est discute des possibilites radiologiques pour poser le diagnostic de la luxation entre les vertebres cervicales inferie ures reconnaissant le fait que les épaules jettent une ombre sur cette région sur les radiographies laterales ordinaires prises chez un malade accidente couché dont les epaules et la partie du cou sont fixes Il est recommande d utiliser des prises laterales tomographiques afin de s assurer que le diagnostic puisse etre pose dès le premier examen

ZUSAMMENFASSUNG

Auf Grundlage von zwei mitgeteilten Krankengeschichten wo eine Verrenkung zwischen C 6 und C 7 bei der ersten Krankenhausaufnahme ubersehen worden war sieht man die Haufigkeit Ursachen und Mecha nismen von Beschadigung der Halswirbelsaule durch Die rontgenolo gischen Möglichkeiten einer Diagnose der Luxation zwischen den unter sten Halswirbeln wird in der Erkenntnis dass die Schultern diese Region auf gewöhnlichen Seitenaufnahmen in liegender Stellung be sonders bei dem beschadigten Patienten mit fixierter Schulter Hals region verdunkeln Man empfiehlt tomographische Seitenaufnahmen zu machen um die Diagnose gleich bei der ersten Untersuchung zu sichern

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CONGENITAL FUNCTIONAL SCOLIOSIS

By

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Congenital functional scoliosis is a fairly rare and relatively unknown type of scoliosis. It has not previously been mentioned in Scandinavian literature. The object of this paper is to describe the appearances of congenital functional scoliosis and to elucidate the differential diagnostic problems in distinguishing it from other types of scoliosis occurring during the first year of life.

Congenital functional scoliosis is taken to mean scoliosis of unknown origin appearing during the first year of life and presumably present at birth and which is possibly due to a faulty intrauterine position. It is a characteristic of this type that it is benign and disappears spontaneously.

This benign scoliosis is called resolving infantile idiopathic scoliosis by Anglo Saxon writers. Some authors (*James* 1951, *Scott* 1956) divide resolving infantile idiopathic scoliosis into 2 sub groups, the resolving type and the postural type. According to *Scott* (1956) the postural type will subside slowly when the infant begins to stand, the standing posture stimulating its disappearance, whereas the resolving type does not disappear in the erect position. This latter type may even progress slightly after the infant starts standing in order to resolve spontaneously at the age of 4–5 years. One author (*Browne* 1956) calls all forms of infantile idiopathic scoliosis postural, and in his opinion they all progress if untreated.

In contrast to this benign type there is the malignant one, progressive infantile idiopathic scoliosis (Figures 4 and 5), also called the progressive type, which usually sets in during the 2nd or 3rd year of life (*James* 1951, *Scott* 1956), although it may be observed as early as the first year. This type is characterized by steady progression throughout the period of growth. The earlier the scoliosis sets in, the greater

is the tendency to progression. This tendency is greater in boys than in girls as their growth period is longer than the girls.

Other types of scoliosis that may occur during the first year of life: structural scoliosis due to congenital malformations (hemivertebrae, etc.) and other types of scoliosis of known aetiology (paralytic, static, etc.) differ clearly from the two types mentioned above and thus fall without the scope of the present study.

PRESENT MATERIAL

During the period 1936 to 1959 a total of 90 patients with congenital functional scoliosis were treated in the Orthopaedic Hospital, Aarhus. No distinction was made between the resolving and the postural type. Out of these 90 patients only 76 are included in the material, 14 being left out as the diagnosis was based exclusively upon the clinical examination without X-ray films. Presumably, these patients did have congenital functional scoliosis since in all cases the scoliosis remained stationary or disappeared during the period that the patients were observed in the Department. Out of the remaining 76 patients 67 were seen by the author in a follow-up which included clinical as well as X-ray examination. The average follow-up period was 12 years (5½–25½ years). The distribution by length of follow-up period is shown in Table 1.

Table 1. Distribution by length of follow-up period

Follow-up period	No. of pts
5–9 years	31
10–14 years	20
15–19 years	10
20–25 years	6

Of the remaining 9 patients 4 stated in letters that the back was straight and normal. One had gone abroad and all attempts at contact have been in vain. The last 4 patients failed to respond to repeated requests to present themselves for a follow-up examination. This makes a follow-up rate of 88 per cent (67 out of 76 patients) as only those patients who had clinical and radiological examination were considered to have been *sufficiently followed*.

Table 2 shows the age at which the scoliosis was discovered by the parents, health visitor or general practitioner at the prophylactic in

fant examination as well as the age at which the patients were first seen in the Orthopaedic Hospital Aarhus

Table 2 Age distribution at detection of scoliosis and at 1st examination at the Orthopaedic Hospital Aarhus

Age in months	Scoliosis detected No of pts.	Seen for the first time in the Orthopaedic Hospital Aarhus. No of pts
1	3	0
2	7	0
3	11	3
4	12	7
5	11	8
6	9	15
7	5	13
8	2	7
9	1	3
10	4	3
11	2	8
12	0	0

The great majority of cases were detected within the first 6 months of life (53 out of 67 or 79 per cent) This is in keeping with statements in the literature *James et al* (1959) reported 4th to 10th month *Scott & Morgan* (1955) 5½ months range 1st to 9th month *Harrenstein* (1936) stated the 3rd to the 7th month but mentioned at the same time that the scoliosis is seldom observed before he 2nd month The progressive type is not diagnosed until much later according to *Scott & Morgan* (1955) at an average age of 15 months *James* (1959) reported that out of 111 scolioses of the progressive type 33 were diagnosed during the 2nd or 3rd year of life Incidentally it is apparent from the table that as a rule about 3 months elapse from the time that the scoliosis is detected until the diagnosis is definitely established

Table 3 Sex ratio and number of left and right sided scolioses

	Girls 29	Boys 38	Total 67
Right sided scoliosis	8	13	21
Left sided scoliosis	21	25	46

Table 3 gives the sex ratio which shows a considerable male pre ponderance viz 38/29 In this respect too the findings are in agree ment with the literature *James et al* (1959) found a ratio boys/girls of 50/27 *Lloyd Roberts & Pilcher* (1965) 67/33 Within the progressive type too *James et al* (1959) found a preponderance of boys 65/46 while *Scott & Morgan* (1955) found the condition to be equally common in both sexes

At follow up 2 patients had complaints in the form of mild pain when overstraining the back and another 2 had more severe pain All were found to have weak insufficient back muscles and the pain was considered of muscular nature All 4 had a curvature of less than 10 3 of them of less than 5

In 9 cases there was clinically very slight scoliosis merely discernible in 6 of the cases In 18 cases there was torsion prominence just dis cernible in 9 while the other 9 had mild but distinct torsion

Table 3 shows moreover that left sided scoliosis was more than *twice as common as right sided* There was no sex difference in this respect *James et al* (1959) as well as *Scott & Morgan* (1955) also found left sided scolioses to be more common and this applies also the progressive type

Table 4 Angle of scoliosis at 1st examination and at follow up

Angle	When first seen No of pts	At follow up No of pts
0– 5	0	47
6–10	15	17
11–15	25	3
16–20	20	0
21–25	4	0
26–30	3	0
	67	67

The degree of scoliosis was measured on the primary X ray films as well as on the follow up films The curve was measured as the angle between the upper plate of the cranial and the lower plate of the caudal vertebra involved in the torsion The primary angle averaged 15 (7– 29) At follow up the corresponding angle was less than 5 in 47 pa tients and as is apparent from Table 4 did not exceed 15 in any case

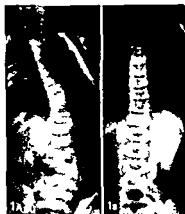


Figure 1 Congenital functional scoliosis (male) A Age 5½ months B Age 6 years

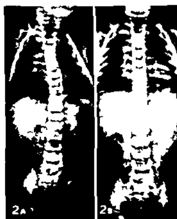


Figure 2 Congenital functional scoliosis (male) A Age 5 months B Age 14 months (not included in the material)

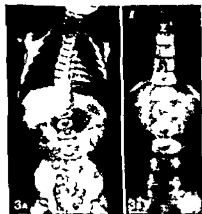


Figure 3 Congenital functional scoliosis (with compensatory curvature) (male) A Age 8 months B Age 7 years

Radiographically most patients showed long soft C shaped single curvatures without compensatory curves (Figures 1 and 2) In one case however there was a hint of compensation (Figure 3) At the primary physical examination 55 patients had exhibited slight posterior torsion of the ribs on the same side as the convexity of the scoliosis In the remaining 12 cases no mention is made of a torsion prominence The number of vertebrae involved in the curve ranged from 6 to 11 average 9 (8 6) The greater part of the curvatures affected the thoracic spine the peak of the convexity corresponding to the 9th or 10th thoracic vertebra (T_9–T_{10}) Table 5 illustrates the site and extent of the scolioses In more than half viz in 38 out of 67 patients or in 57 per cent of the scolioses the uppermost vertebra was T_5–T_7 and the lowermost L_1–L_2

Table 5 Extent of scoliosis Uppermost (vertical column) and lowermost (horizontal line) involved vertebra

	T_1	L_1	L	L_3	Total
T_4	3	4	3		10
T_5	3	9	8	2	2[illegible]
T_6	1	8	7	1	17
T_7		1	6		7
T_8		3	4	1	8
T_9			1	2	3

James et al (1959) found the majority of curvatures to be 11–20, *Scott & Morgan* (1955) below 20 Moreover the latter found torsion to be minimal while in the progressive type the curvature was seldom below 20 and the torsion more pronounced already at the first examination In the progressive type moreover there is compensatory curvature (Figures 4 and 5) which is rarely present in the functional type (Figures 1 and 2) *Scott & Morgan* (1955) also found the progressive types to involve fewer vertebrae than the functional type 3–8 vertebrae in the progressive as compared with 5–10 in the functional type

During the period 1936–1954 44 cases of congenital functional scoliosis were diagnosed in the Orthopaedic Hospital Aarhus as compared with 4 cases of the progressive type This means a frequency of progressive scoliosis of 8 3 per cent but no doubt this is too high as some of the functional cases are never seen by an orthopaedic surgeon or



Figure 4 Infantile progressive idiopathic scoliosis (female) A Age 11 months B Age 19 months C Age 13 years

will simply be overlooked and thus never be recorded whereas the progressive cases are bound to be sent for treatment in an orthopaedic department *Lloyd Roberts & Pilcher* (1965) reported a frequency of 8 per cent

Prior to 1955 12 of the most severe cases of congenital functional scoliosis were treated in a plaster or celastic bed Two patients were treated in a corrective bed the trunk being bent to the side of the convexity of the scoliosis Patients seen after 1955 have received no treatment at all



Figure 5 Infantile progressive idiopathic scoliosis (male) A Age 10 months B Age 10 years

DIAGNOSTIC CRITERIA

The typical patient with congenital functional scoliosis is a healthy normal looking boy of 6–7 months in whom the parents have noted a curvature of the spine stationary through a couple of months The thoracic spine shows a long very mild most often left sided scoliosis with slight torsion prominence of the ribs but no compensatory curvature This scoliosis does not disappear when the baby is held suspended by the arms X rays reveal a long soft C shaped single curve with slight torsion and no compensation The apex of the scoliosis is at T_9 or T_{10} and it involves about 9 vertebrae which exhibit *no congenital* malformations In most cases the scoliosis is localized within the area of T_6–L

The main problem is to distinguish the benign type of congenital functional scoliosis from malignant infantile idiopathic scoliosis as early as possible During the first year of life it is usually impossible to decide with certainty whether a scoliosis is going to progress or to disappear The functional type involves a larger number of vertebrae and has no compensatory curvature Besides it shows a lesser angle and less torsion and it sets in at an earlier age The progressive type is far less common than the functional type

Only close observation can afford the answer Therefore the congenital functional scolioses have to be followed until they have disappeared or have remained stationary and very mild for a long time As a rule this cannot be decided until the age of 2 years

SUMMARY

The most important types of scoliosis which may occur during the first year of life are briefly reviewed A follow up on a material of 67 patients with congenital functional scoliosis is reported Average follow up period was 12 years At follow up practically all the scolioses had straightened spontaneously The appearances of congenital functional scoliosis are described and the most important differential diagnostic criteria from infantile progressive idiopathic scoliosis are discussed It is concluded that a distinction between the two types can be made only by frequent examinations during the first years of life

RESUME

Les types les plus importants de scolioses qui peuvent se produire pendant les premières annees de la vie sont passes en revue L obser

vation de 67 malades atteints de scoliose congenitale fonctionnelle est exposes La periode moyenne d observation a ete de 12 ans On a constate au cours de ces observations que pratiquement toutes les scolioses se sont redressees spontanement Les aspects de la scoliose fonctionnelle congenitale sont decrits et il est discute des criteres les plus importants du diagnostic differentiel de la scoliose idiopathique infantile progressive Il est conclu que seuls des examens frequents durant la première annee de la vie permettent d etablir une distinction nette entre ces deux types de maladies

ZUSAMMENFASSUNG

Die wichtigsten Typen von Skoliose welche im ersten Lebensjahre auftreten können werden in Kurze durchgegangen Eine Nachunter suchung eines Materiales von 67 Patienten mit kongenitaler funktioneller Skoliose wird vorgelegt Die durchschnittliche Beobachtungszeit war 12 Jahre Bei der Nachuntersuchung hatten sich fast alle Skoliosen von selbst ausgerichtet

Das Aussehen der kongenitalen funktionellen Skoliose wird be schrieben und die wichtigsten differential diagnostischen Unterschiede von der infantilen progressiven idiopathischen Skoliose werden be sprochen Man schliesst dass eine Unterscheidung beider Arten nur mittels häufiger Untersuchung in den ersten Lebensjahren gemacht werden kann

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LONG TERM PROGNOSIS IN IDIOPATHIC SCOLIOSIS

By

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Received 2 ii 68

The prognosis in idiopathic scoliosis has chiefly been discussed in terms of the possibility of forecasting the progress of a curvature observed at the onset of the disease It is of course understandable that the ortho pedic surgeon should concentrate on patients whose age makes them particularly susceptible to progression of the scoliosis and that most attention should then be paid to the opportunities for active therapy At the same time little is known about the fate of scoliotic patients after they have left the orthopedic surgeon s immediate field of interest There are a number of general statements (*e g* *Kleinberg* 1951 *Margret Lange* 1962) to the effect that patients with severe scoliosis generally die before the age of 45–50 the deformation of the thorax impairing the heart lung function and thereby resulting in an increased mortality *Chapman et al* (1939) in a group mainly composed of paralytic scolioses even give a worse prognosis with an average death age of 30 years *Sulser* (1958) on the other hand reports that in an autopsy material the average death ages in kypho scoliotic individuals were in agreement with those of the general population of Switzerland The material was however rather mixed and even included osteoporotic changes of the spine in old patients Thus it would seem that no systematic study has been published of the long term prognosis in a pure group of idiopathic scoliosis

The present study on a group of patients with an observation time of up to 50 years contains an analysis of the vital prognosis in idiopathic scoliosis and an account of the social and socio medical function of these patient A preliminary report has already been published (*Nilsonne & Lundgren* 1964)

MATERIAL

The study comprises a group of patients with idiopathic scoliosis who came to the Orthopaedic Clinic in Stockholm in the period 1/7 1913–30/6 1918 i e the first five years after the Clinic opened

The concept of idiopathic scoliosis does not appear as a diagnosis in the case reports from that time The earliest instance of this terminology that we were able to find in the literature dated from 1922 (*Kleinberg*) The Orthopaedic Clinic s records of diagnoses from the period covered by this study contain a variety of terms including scoliosis rachitica scoliosis congenita scoliosis habitualis scoliosis essentialis and insufficientia vertebrae moreover these diagnoses are usually accompanied by a question mark to denote the examining physician s uncertainty about the etiology

Some importance used to be attached to rickets as a cause of progressive scoliosis but this has been refuted by more recent investigations (e g Brunk 1951) Nearly all the present case reports include an ordinary full length photograph of the patient none of which display any external signs of deformities that might suggest rickets It is thus most unlikely that any patient with rickets has been included in this investigation

The available case reports contain very little if any information about the duration of the scoliosis and consequently the present cases may include an occasional instance of congenital scoliosis e g due to vertebral malformation This source of error cannot be very large however since the maximum incidence of congenital scoliosis is reported to be 5 per cent (*Kleinberg* 1951)

The photographs and in some cases X ray pictures show that the other diagnostic terms exemplified above refer to structural not functional scolioses

The records from the period covered by this study include a large number of paralytic scolioses arising from polio Since the sequelae of polio were a central orthopaedic problem at that time we have accepted the diagnosis of paralytic scoliosis and such cases have been excluded

Table 1 Distribution of patients by year of admission

	1913	1914	1915	1916	1917	1918	Total
M	2	1	4	8	9	1	25
F	8	19	19	17	17	8	88
M + F	10	20	23	25	26	9	113

(In this and the following tables M = males F = females)

With these criteria we have arrived at a group of patients whose diagnosis in modern terms would be idiopathic scoliosis. The patients either received no treatment or else they were prescribed physiotherapy and/or a supporting brace No active attempts were made to correct the scoliosis by conservative or surgical means. From the modern point of view the material may be regarded as a group of untreated patients with idiopathic scoliosis.

The composition of the material is presented in Table 1, which also shows the number of new cases per year during the period of the study. The total material comprises 113 patients, 88 female and 25 male. The female incidence is thus 78 per cent, which is in good agreement with the recognized sex difference in idiopathic scoliosis (*Lindeman* 1958), namely that rather more than three times as many females contract the disease as males.

Table 2. Distribution by age at admission

Age at admission	M	F	M + F
7–9	4	6	10
10–14	4	36	40
15–19	11	33	44
20–24	4	7	11
25–29	1	4	5
30–34	1	2	3
Total	25	88	113

The distribution by age at the time of admission is given in Table 2. (The ages represent the difference between the year of admission and the year of birth.) The mean age on admission for the total material is 15.9 years, while for the males it is 16.7 years and for the females 15.6 years (see also Table 5). These average ages seem to be higher than they are today, no doubt because the improved medical control of school children now results in an earlier orthopaedic assessment of any back trouble. If instead the mean age on admission is calculated only for those patients in whom the scoliosis had not yet become stationary, the result is 13.[illegible] years for the females and 12.5 years for the males (assuming that skeletal growth and hence the progression of the scoliosis had ceased in women of 17 or more and in men of 18 or more, so that these cases are excluded). This indicates that a large proportion of the patients with idiopathic scoliosis in the period 1913–1918 were observed during the progressive stage in puberty, when they were roughly the same age as the patients encountered today.

VITAL STATISTICS

Inquiries were made to find out whether or not the patients were still alive at the time of this study. In the case of those who had died, the year and the cause of death were ascertained from the parish registry office. In most cases it was possible to obtain the case reports on these patients' last hospitalization and thereby confirm the reported cause of death. Further verification was obtained in many cases from the autopsy report. The patients have been followed up to the middle of 1963, which thus constitutes the end of the observation period for the living

individuals The reported ages were calculated as the difference between the last year of observation (1963 or the year of death) and the year of birth Eleven of the 113 patients could not be traced because the personal data in the records were too scanty to permit re identification in the ordinary population register

The distribution between living and dead patients is given in Table 3 Of all those who could be traced 56 were alive and 46 had died at the time of this study the corresponding figures for the 25 males being 10 alive and 12 dead (3 not traced) and for the 88 females 46 alive and 34 dead (8 not traced)

Table 3 Distribution by living dead and not followed

	M	F	M + F
Living 1963	10	46	56
Dead	12	34	46
Not followed	3	8	11
Total	25	88	113

Table 4 Mean age of living and dead patients

	Living 1963 No	Mean age
M	10	60 0
F	46	62 6
M + F	56	62 1
	Dead No	Mean age
M	12	51 9
F	34	44 8
M + F	46	46 6

The mean ages of the living and the dead patients are given in Table 4 There is a considerable difference between these groups the mean age for the former being 62 1 years and for the latter 46 6 years In the dead group the mean age of the women at the time of death 44 8 years is definitely lower than that for the men 51 9 years

The mean age of all the patients at the time of their first visit to the Clinic is given in Table 5 Those who have died were older at their first

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Table 7 Number of observed (O) and expected [illegible]

	M		F	
	O	E	O	[illegible]
Period				
1913–20		0 6	[illegible]	[illegible]
1921–30		0 9	[illegible]	[illegible]
1931–40		0 9	2	[illegible]
1941–50	9	0 8	11	[illegible]
1951–60	2	1 1	1	[illegible]
1961–63	1	0 4	1	[illegible]
Age				
7–19		0 4	[illegible]	[illegible]
20–34		1 4	6	[illegible]
35–49	5	1 3	12	[illegible]
50–64	7	1 6	11	
65		0 0	2	
7–44	2	2 6	1[illegible]	
45–	10	2 1	21	
Total	12	4 7	34	

Table 8 Mortality ratio (O [illegible]

Age	M			F	
	O	E	O/E	O	E
7–44	2	2 6	0 8	13	[illegible]
45–	10	2 1	4 8	21	7[illegible]
Total	12	4 7	2 5	34	1[illegible]

Table 7 presents a comparison betwe[illegible] at served and the number expected The d[illegible] th cades as well as by age the calculations [illegible] 47 for the Swedish population It will be [illegible] siderably higher than expected partic[illegible] thus 20 deaths in the period 1941–50 co[illegible] of only 3 7 As far as age is concerned [illegible] that mortality is higher than expected [illegible] 0 6 expected

The relationship between observed a[illegible] idio- expressed as a mortality ratio (Table [illegible] who [illegible] tality [illegible] jority

group over 45 years of age For the men in this group the mortality ratio is extremely high 4 8 but here it should be noted that the mortality for men is about 20 per cent higher in Stockholm than in the rest of Sweden (*Larsson 1965*) to some extent therefore this high figure may reflect the fact that 11 of the 25 males were resident in the city or county of Stockholm at the time of their first visit to the Clinic The mortality ratio for all the patients aged 45 or more is 3 2 while that for the entire material is 2 2 In other words the mortality in idiopathic scoliosis in this material is more than twice as high as in the general population

Table 9 Distribution by cause of death

Cause of death	Sex		Age at death	
	M	F	M	F
Pulmonary disease	1	11	53	18 18 19 20 24 33 39 45 45 45 54
Cardiac incompensation	7	9	39 44 47 48 51 51 54	27 33 38 41 46 47 48 54 56
Arteriosclerosis	3	6	62 63 64	55 62 64 64 67 76
Tumour	1	4	47	33 44 45 57
Other		4		48 50 50 57
Total	12	34		

The causes of death are reported in Table 9 Lung disease comprises pulmonary tuberculosis and pneumonia Cardiac incompensation refers to the patients who died in right heart failure In several of these cases the death certificate even mentions the term kyphoscoliotic heart Under arteriosclerosis the causes of death were cerebral haemorrhagia and cardiosclerosis Only malignant tumors are included under tumor Other causes of death include suicide and delirium

Cardiac or pulmonary disease accounted for about 60 per cent of the deaths The age at death is also given in Table 9 which shows that 13 of the 28 cases of heart or lung disease died before the age of 45

SOCIAL AND SOCIOMEDICAL ASPECTS

Besides suffering cosmetically patients with idiopathic scoliosis have a reduced physical work capacity particularly in severe cases The

marriage rate for the females in this material (excluding those not traced) has been taken as a measure of the social function About 76 per cent are unmarried (Table 10) The proportion of married women is higher among the living patients which might be expected since they have had more time in which to find a partner Nevertheless the figures show that an extremely large proportion of women with idiopathic scoliosis do not marry

Table 10 Distribution of followed women by marital status

F	No	Unmarried No	Unmarried %
Living	46	31	67
Dead	34	30	88
Total	*80*	*61*	*76*

Table 11 Orthopaedic and disablement status for 50 living patients (see text)

Mean age living	62 1 years
Back symptoms	90 %
Disablement pension for scoliosis	30 %
Disabled but no pension	17 %

A questionnaire was distributed to all the living patients asking about their work function and any subjective back trouble Answers were received from 50 out of 56 Back symptoms were reported by 90 per cent (Table 12) mostly in the form of a feeling of tiredness or pains in the thoracic or lumbar spine on exertion Many of the patients had used some type of corset most of their lives Of those who answered 30 per cent stated that they had received a disablement pension for their back trouble while a further 17 per cent considered that they were unable to work and had apparently managed by living with their parents or relatives most of their lives Altogether therefore 47 per cent of the living patients were disabled

CONCLUSIONS

The study shows that there is an abnormally high mortality in idiopathic scoliosis The average mortality among the 102 patients who could be traced is twice that in the normal population The mortality appears to be highest *after the age of 45* *However* since the majority

of the 11 patients who could not be traced and who were therefore excluded from the mortality calculations probably died in the early part of the observation period it is possible that the actual mortality before the age of 45 is higher than indicated by the present figures Cardiac or pulmonary disease was the cause of death in 60 per cent of the patients who died

Idiopathic scoliosis may also involve a social and sociomedical handicap The cosmetic deformity is reflected in an extremely high proportion of unmarried women Imbalance in the spinal column is evident from the markedly high incidence of subjective back trouble An indication of the effect on the physical work capacity is provided by the finding that almost half of the living patients are unable to work

These circumstances must be borne in mind when assessing the seriousness of a newly discovered case of idiopathic scoliosis

SUMMARY

113 cases of idiopathic scoliosis (88 females 25 males) first noted in the period 1913–18 were followed up to 1963 The material presents a marked hypermortality with a mortality ratio of 2 2 Cardiac or pulmonary disease was the cause *of death in 60* per *cent of the individuals* who died The sociomedical effects of scoliosis are reflected in the very high proportion of the women who have not married as well as in the *high percentage of the living individuals who are unable to work*

ACKNOWLEDGEMENT

Mr *Tage Larsson* M D F L Chairman of the Medical Research Council of the Swedish Life Offices has given us kind and valuable advice in the statistical approach for which we are most grateful

RESUME

113 cas de scoliose idiopathique (88 femmes 25 hommes) observés pour la 1ere fois entre 1913 et 1918 ont été suivis jusqu en 1963

L échantillon presente une hypermortalité marquée avec un rapport de mortalite de 2 2

Les maladies cardiaques ou pulmonaires ont ete les causes de la mort de 60 pour cent des individus décédés

Les effets sociaux médicaux de la scoliose se traduisent par une proportion elevée de femmes qui ne se sont pas mariees ainsi que par un haut pourcentage d individus vivants incapables de travailler

ZUSAMMENFASSUNG

113 Fälle von idiopatischer Skoliose (88 weibliche 25 männliche) erstmalig registriert während der Periode 1913–1918 wurden bis zu 1963 beobachtet Dieses Material zeigt eine markante Hypermortalität mit der Mortalitätsratio von 2 2 Herz und Lungenkrankheiten waren die Todesursache in 60 Prozent der Todesfälle Die Sozialmedicinische Bedeutung der Skoliose tritt in der hohen Zahl der unverheirateten Frauen sowie in der hohen Zahl der nicht arbeitsfähigen Individen hervor

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A LONG TERM FOLLOW UP STUDY OF NON TREATED SCOLIOSIS

By

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It is a well known fact that severe lateral curvature of the spine causes respiratory disturbances and an overload of the lung and the heart (1 2 5 9 10 17 20) Reports have been published on the effect in the respiratory volume in scoliotic patients and it has been said that curvatures about 50 to 60 will cause considerable lowering of the vital capacity in these patients (6 7 8 14) Other reports have been published on the indirect effect on the heart (2 5 10) Thus we know that a lateral curvature will decrease the vital capacity but very few papers have been published on the life expectancy in these patients

In large autopsy materials severe scolioses have been found in 0 5 per cent (20) In such studies the mean age at death (30–50 years) for corpses with lateral curvatures of their spines has been found to be lower than for the average population especially if these curves were known to have started adolescence (5 17 20) In a communication of a 50 year follow up on 113 cases of idiopathic scolioses who were seen 1913–1918 in Stockholm *Nilsonne & Lundgren* (15) reported a 100 per cent increase in mortality compared to people born in the year 1900

Previous follow up studies have been concerned mainly with the result of different types of non operative and operative treatment These however cover only a limited period of time up to the end of the growth period of the patients (3 4 11 13 16 18 19 22) While the results of non operative treatment have been very discouraging with the exception of the Milwaukee brace (3 4) opinions differ with regard to the result of the operative treatment It is obvious however from the latest reports that more and more drastic measures have been adopted in order to achieve and secure a straight spine (11 12 19 22) Wedge resections of vertebral bodies and different kinds of internal

supports have been advocated Today the operative treatment of scoliosis is often of great magnitude and mortality has been reported (11)

It would therefore be of interest to have a long term follow up on untreated scoliotic patients with regard to life expectancy and to working capacity This of course is regardless of the cosmetic disability which always exists

MATERIAL

This material consists of those patients with a scoliosis who looked for medical advice to the Department of Orthopaedic Surgery in Gothenburg during the years 1927 to 1936

During these years all patients in the western part of Sweden covering a population of about 1 900 000 people were sent here for orthopaedic advice and it can certainly be said that most of the patients with a lateral curvature of the spine of some magnitude in this region were seen However at that time no treatment was advised except occasional stretch exercises

From the available charts it is impossible to say how bad the curves were but in about 50 per cent of the cases photographs of the back was taken No roentgenograms were made The possible etiology of the scoliosis and the age when the curve was first noticed are also listed The curve was regarded as congenital if it was noticed under the age of 1 year With regard to the purpose of this paper it is considered of relatively minor importance whether it was a definite congenital curve or a structural infantile scoliosis The miscellaneous group consists of two cases of scoliosis due to tuberculosis of the spine one case of neuro fibromatosis and one case of thoracogenic curve

Table 1 Etiology sex and direction of main curve in the thoracic or thoracolumbar region in 130 patients

Curve convex to	Idiopathic ♂	Idiopathic ♀	Rachitogenic ♂	Rachitogenic ♀	Poliomyelitic ♂	Poliomyelitic ♀	Congenital ♂	Congenital ♀	Miscellaneous ♂	Miscellaneous ♀
Right	12	40	3	10	[illegible]	10	3	3	1	–
Left	–	7	7	8		5	7	2	2	2
	59		[illegible]		23		15		5	

In this report only those patients were followed who during the above mentioned period of time were under the age of 25 years at their first visit. A total of 130 patients fall into this category It was not possible to differentiate between either the localization or the exact extent of the curves

It is seen from Table 1 that 75 per cent were women and 25 per cent men The composition of the material with regard to the different etiological groups, sex and direction of the curve does not differ much from other materials (18 19 20 22)

The average age of the patients at their first visit was 14 years (1–25 years)

Table 2 Causes of death 20 patients out of 117

Age of patient when first seen	Sex	Type of curve according to orig records	Age at death	Main cause of death
9	♀	idiopathic right sided thoracic	42	kyphoscoliotic cardiopathy with cor pulmonale
12	♀	poliomyel right sided thoracic	44	kyphoscoliotic cardiopathy with cor pulmonale
25	♂	idiopathic right sided thoracic	44	kyphoscoliotic cardiopathy with cor pulmonale
25	♀	rachitog right sided thoracic	36	*kyphoscoliotic cardiopathy* with cor pulmonale
16	♀	tbc spondylitic left sided thoracic	16	Nephritis
17	♀	idiopathic right sided thoracic	43	Suicide
16	♀	polio right sided thoracic	44	kyphoscoliotic cardiopathy *with cor pulmonale*
9	♀	rachitog right sided thoracic	43	kyphoscoliotic cardiopathy with cor pulmonale
9	♀	congenital right sided thoracic	30	kyphoscoliotic cardiopathy with cor pulmonale
15	♂	rachitog right sided thoracic	24	kyphoscoliotic cardiopathy with cor pulmonale
12	♀	rachitog left sided thoracic	40	kyphoscoliotic cardiopathy with cor pulmonale
13	♀	idiopathic left sided thoracic	24	Uremia
20	♂	polio right sided thoracic	34	kyphoscoliotic cardiopathy with cor pulmonale
11	♀	*congenital* left sided cervicodorsal	44	kyphoscoliotic cardiopathy with cor pulmonale

Table 2 (cont)

Age of patient when first seen	Sex	Type of curve according to orig records	Age at death	Main cause of death
1	♀	congenital left sided thoracic	23	Kyphoscoliotic cardiopathy with cor pulmonale
17	♀	neurogen left sided thoracic	40	Carcinoma of the uterus
25	♂	rachitic right sided thoracic	45	Kyphoscoliotic cardiopathy with cor pulmonale
15	♀	idiopathic right sided thoracic	50	Kyphoscoliotic cardiopathy with cor pulmonale
16	♀	congenital right sided thoracic	46	Kyphoscoliotic cardiopathy with cor pulmonale
19	♀	polio left sided thoracic	8	Kyphoscoliotic cardiopathy with cor pulmonale

RESULT OF THE FOLLOW UP IN 1966

It was possible to trace a total of 117 patients Of these 20 were dead as listed in Table 2 It can be seen that 16 of these died from cardio-pulmonary diseases probably related to the lateral curvature of the spine

A statistical analysis was made to show the number of deaths in an average Swedish population with the same age and sex distribution as the present material The number of expected deaths in such a material was 10 4

The observed number in this material was 20 This obviously is a statistically significant increase

When the material was divided into etiological groups as in Table 3 it was also found that the number of deaths in the two groups con genital and miscellaneous were significantly raised in comparison with the idiopathic group

Those 97 patients that were still alive and were located all replied to a questionnaire where they had to state

4 Of those engaged in full time work 48 had some kind of light occupation while 21 were in medium hard work No one was occupied in hard manual labour

5 Pain in the back was a relatively constant finding in 39 of the 97 patients and this symptom was found in about the same percentage in all the different etiological groups

6 Only 24 patients used a brace or corset of any kind

DISCUSSION

This follow up study on 117 patients with lateral curvature of the spine shows that the deformity irrespective of what its cause might be is a very serious one It confirms that a severe scoliosis causes grave disturbance in the function of the lungs and the heart

The original material consisted of 130 patients but 13 of these could not be traced With regard to age sex and type of scoliosis this group did not differ from the rest of the material and the outcome of these patients with all probability will not alter the conclusions presented

From the results it is shown that this group of patients suffered from nearly 100 per cent increased mortality as compared to the general population It should be emphasized that the present material also comprises a number of less severe curves but as previously mentioned it was impossible from the available charts to draw any conclusion regarding the severity of the curve since no roentgenograms were made It can only be said that in the group of 97 surviving patients contacted the curve was noted to be minor in 12 In none of the charts of the deceased could this statement be found Thus with all probability the mortality rate of a severe scoliosis (80 or more) is well over 100 per cent compared to the average population

This is also supported by the fact that the highest mortality rate was found in the groups congenital and miscellaneous Such curves are known to progress to very severe ones in most cases (13 19) Table 3

The decreased ability to perform ordinary work of these patients is seen from the number claiming disability compensation 24 of the 28 patients not working blamed their incapacity on their scoliosis or related diseases

A comparison can be made with an investigation performed in 1963 on 973 men in Goteborg born in the year 1913 Of these 23 (2 5 per cent) claimed disability compensation 13 of those on psychiatric grounds Of the remaining 950 men one third was occupied in heavy labour one third in medium hard work and one third had some kind of collar work (21)

In the present group of 97 patients that was followed there were 32 men who were seen or contacted at the average age of 48 years Of these 7 could not perform any work at all (22 per cent) while 15 (60 per cent) were engaged in collar work and 10 (40 per cent) had a medium hard work No one was occupied in heavy labour

Thus it is clear that lateral curvature of the spine also reduces the working capacity to a very great extent

Pain in the back was a relatively constant symptom in 39 of the 97 patients followed This is probably due to the severe degree of osteo-arthritic changes that always will occur in these patients Two patients reported constant severe disabling pain

Only 25 of the 97 patients reported a constant use of brace or corset in spite of the fact that these are given to the patients at no expense in Sweden

The follow up results obtained in the twelve patients who were examined by the author are included in the above presentation In three of these patients roentgenograms revealed a primary lumbar curve

It is known that those with low thoracolumbar or lumbar curves will be less disabled from cardio pulmonary insufficiency (7 20) Unfortunately it was not possible to differentiate the exact extent and site of the primary curve from the charts available It is probable however that in the number of patients surviving without disability a relatively high proportion of primary lumbar curves is to be found

It is thus likely that the increased rate of mortality in patients with a cervico dorsal or dorsal scoliosis of some severity will be higher than the 100 per cent found in this general material

SUMMARY

This long term follow up of non treated scoliotic patients was done to evaluate the disability and eventual increased mortality rate that could be suspected from our knowledge of the pulmonary and cardiac distress that develops in some of these patients Of the 130 patients who were seen in the department from 1927–1936 117 could be traced Of these 20 were deceased In a similar group of the general population the number of expected deaths were 10 4 16 of the patients in this material died from kyphoscoliotic cardiopathy with cor pulmonale

With regard to the etiology of the lateral curve the congenital thoracogenic and neurogenic ones were found to have a worse prognosis than the idiopathic rachitogenic and poliomyelitic scoliosis

4 Of those engaged in full time work 48 had some kind of light occupation while 21 were in medium hard work No one was occupied in hard manual labour

5 Pain in the back was a relatively constant finding in 39 of the 97 patients and this symptom was found in about the same percentage in all the different etiological groups

6 Only 24 patients used a brace or corset of any kind

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From the results it is shown that this group of patients suffered from nearly 100 per cent increased mortality as compared to the general population It should be emphasized that the present material also comprises a number of less severe curves but as previously mentioned it was impossible from the available charts to draw any conclusion regarding the severity of the curve since no roentgenograms were made It can only be said that in the group of 97 surviving patients contacted the curve was noted to be minor in 12 In none of the charts of the deceased could this statement be found Thus with all probability the mortality rate of a severe scoliosis (80 or more) is well over 100 per cent compared to the average population

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SUMMARY

This long term follow up of non treated ... evaluate the disability and eventual ... be suspected from our knowledge of the ... that develops in some of these patients ... seen in the department from 1927-19... 20 were deceased. In a similar ... number of expected deaths were 10 ... died from kyphoscoliotic cardiopathy ...

With regard to the etiology of ... racogenic and neurogenic ones were ... than the idiopathic rachitogenic ...

In 39 out of 97 patients pain in the back was noted as a commonly occurring symptom

RESUME

Cet examen à long terme chez des malades scoliotiques qui n'ont pas subi de traitement a été effectué pour juger de leur incapacité de travail et éventuellement du taux plus élevé de mortalité que l'on pouvait soupçonner en partant des connaissances que nous avons des troubles pulmonaires et cardiaques qui se développent chez certains de ces malades. Il a été possible de retrouver la trace de 117 des 130 malades observés dans notre Département entre 1927 et 1936. 20 d'entre eux étaient décédés. Dans un groupe correspondant de la population générale le nombre des décès aurait vraisemblablement été de 10.4. 16 des malades appartenant à ce matériel sont décédés de cardiopathie cyphoscoliotique avec coeur pulmonaire. En ce qui concerne la capacité de travail il a été constaté que celle-ci était fortement diminuée par comparaison avec la population générale.

Par rapport à l'étiologie de la courbure latérale on a constaté que les formes congénitales, thoracogéniques et neurogéniques ont un pronostic plus favorable que les scolioses idiopathiques, rachitogéniques et poliomyélitiques.

Chez 39 des 97 malades des douleurs dorsales ont été observées comme un symptôme très courant.

ZUSAMMENFASSUNG

Diese Langfristuntersuchung von nicht behandelten skoliotischen Patienten wurde ausgeführt, um die Invalidität und möglicherweise erhöhte Sterblichkeit zu bewerten, die man von unserem Wissen hinsichtlich der pulmonalen und kardialen Schwierigkeiten, die sich bei einigen dieser Patienten entwickeln, vermuten konnte. Von den 130 Patienten, die an der Abteilung von 1927–1936 gesehen worden waren, konnten 117 verfolgt werden. Von diesen waren 20 gestorben. In einer gleichen Gruppe der allgemeinen Bevölkerung ist die Zahl der erwarteten Todesfälle 10.4. 16 der Patienten in diesem Materiale starben in kyphoskoliotischer Cardiopathie mit einem cor pulmonale. Hinsichtlich der Arbeitsfähigkeit fand man, dass diese im Verhältnis zur allgemeinen Bevölkerung sehr herabgesetzt war.

Hinsichtlich der Ätiologie der lateralen Kurve wurde gefunden, dass die kongenitalen, thorakogenen und neurogenen Skoliosen eine schlech

tere Prognose haben als die idiopathischen rachitogenen oder polio myelitischen

Bei 39 von 97 Patienten wurden Ruckenschmerzen als ein gewohnlich vorkommendes Symptom beobachtet

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In 39 out of 97 patients pain in the back was noted as a commonly occurring symptom

RÉSUMÉ

Cet examen à long terme chez des malades scoliotiques qui n ont pas subi de traitement a ete effectue pour juger de leur incapacite de travail et eventuellement du taux plus eleve de mortalite que l on pouvait soupçonner en partant des connaissances que nous avons des troubles pulmonaires et cardiaques qui se developpent chez certains de ces malades Il a ete possible de retrouver la trace de 117 des 130 malades observes dans notre Departement entre 1927 et 1936 20 d entre eux etaient decedes Dans un groupe correspondant de la population générale le nombre des decès aurait vraisemblablement ete de 10 4 16 des malades appartenant a ce materiel sont decedés de cardiopathie cyphoscoliotique avec coeur pulmonaire En ce qui concerne la capacite de travail il a ete constate que celle ci etait fortement diminuee par comparaison avec la population generale

Par rapport a l étiologie de la courbure laterale on a constate que les formes congenitales thoracogeniques et neurogeniques ont un pronostic plus favorable que les scolioses idiopathiques rachitogeniques et poliomyelitiques

Chez 39 des 97 malades des douleurs dorsales ont eté observees comme un symptome tres courant

ZUSAMMENFASSUNG

Diese Langfristuntersuchung von nicht behandelten skoliotischen Patienten wurde ausgefuhrt um die Invaliditet und moglicherweise erhohte Sterblichkeit zu bewerten die man von unserem Wissen hinsichtlich der pulmonalen und kardinalen Schwierigkeiten die sich bei einigen dieser Patienten entwickeln vermuten konnte Von den 130 Patienten die in der Abteilung von 1927–1936 gesehen worden waren konnten 117 verfolgt werden Von diesen waren 20 gestorben In einer gleichen Gruppe der allgemeinen Bevolkerung ist die Zahl der erwarteten Todesfalle 10 4 16 der Patienten in diesem Materiale starben an kyphoskoliotischer Cardiopathie mit einem cor pulmonale Hinsichtlich der Arbeitsfahigkeit fandt man dass diese im Verhaltnis zur allgemeinen Bevolkerung sehr herabgesetzt war

Hinsichtlich der Atiologie der lateralen Kurve wurde gefunden dass die kongenitalen thorakogenen und neurogenen Skoliosen eine schlech

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RUPTURE OF THE ROTATOR CUFF OF THE SHOULDER

Experiences of Surgical Treatment

By

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Undisturbed synchronous function of the glenohumeral acromioclavicular and sternoclavicular joints and of the socalled scapulothoracal and supraglenoidal joints is indispensable for normal mobility in the shoulder joint The supraglenoid joint is formed by the acromion and the coracoid process with the coracoacromial ligament on the one hand and the rotator cuff with the biceps tendon on the other with the subacromial bursa as joint capsule The significance of this joint and of the smoothness of its surfaces should not be underestimated

The muscles whose tendons together with the joint capsule form the rotator cuff strain the latter and it has been assumed that the main task of the supraspinatus muscle is to pull down and fix the humeral head against the glenoid cavity when at the initial stage of abduction the deltoid muscle tends to displace the humerus in direction of its longitudinal axis When *Olsson* (9) observed that after rupture of the subscapularis tendon abduction was no longer possible he concluded that fixation is principally secured by the subscapularis and teres minor muscles However *da Palma* (10) demonstrated that abduction was undisturbed even after extensive lesion of the rotator cuff By selective blocking of the suprascapularis nerve *van Linge et al* (5) demonstrated that as long as the rotator cuff was intact failure of the supraspinatus function did not affect the extent but only the strength of abducion They concluded that the only specific function of the supraspinatus muscle was to strain the rotator cuff and that in rupture of the cuff the functional disturbance was due to impaction of the injured tendom between the humerus and the acromion

Rupture of the rotator cuff does not always give rise to disturbances

requiring treatment or even leading the victim to seek medical advice Normal ageing is accompanied by degenerative processes which, in the rotator cuff first appear at a distance of about 1 cm from the greater tuberosity where the nutrition is poorest (*Rothman et al* (11)) and where the capsule is tightly stretched over the humeral head while the demand for a buffer effect against the acromion is greatest in abduction Here both complete (full thickness) and incomplete ruptures of the rotator cuff occur and can be observed at autopsy in 20 to 30 per cent of all persons over 60 years old

A sudden usually traumatic rupture however causes functional disturbances and pain These symptoms occur emediately but may also not appear until a few days later possibly as a result of secondary traumatic bursitis (*Kernwein et al* (4)) The symptoms may subside spontaneously or after conservative treatment However in considering da Palma s opinion that 90 per cent of all persons with rupture of the rotator cuff recover without surgical treatment it must be remembered that his series included both complete and incomplete ruptures and that the condition cannot always be diagnosed with certainty

Since 1933 when *Codman & Oberholzer* performed the first arthrography of the shoulder joint the method has been developed and we have learned to diagnose total rupture of the rotator cuff arthrographically Thus a safer basis has been obtained for prognosis and for assessment of the results of treatment and operative indications However opinions are still divided as to the best method of treatment While *Wachsmuth* (13) writes Reine Abrisse erfordern in fast jedem Falle eine operative Behandlung da sonst eine erhebliche Funktionsein schränkung zurückbleibt others recommend operative treatment only when good abduction is not restored by conservative treatment for 1 to 1½ months *Da Palma* (10) 2 to 4 months *Campbell* (2) or 4 to 6 months *Debeyre et al* (3) *Adams* (1) does not advocate operative treatment of elderly patients as a rule and *Magnusson* (6) is of the opinion that it is *contraindicated in all inveterate cases and in recent cases when the* patient is over 40 years old

In view of these opinions I have felt it justifiable to report my experience of a series of 30 cases of rupture of the rotator cuff treated at the General Hospital Bjorneborg (Pori) during the period June 1959–June 1964 In 22 operatively verified cases there was complete rupture of at least 1 cm width while in 4 out of 8 conservatively treated cases arthrography indicated a small complete rupture and in 4 cases a probable diagnosis of incomplete rupture was made on the basis of

clinical examination (Thus the conservatively treated cases were estimated to be less severe than the operatively treated and the groups are not therefore comparable)

The series consists of 16 men and 14 women aged 40–67 years The average age 56 years was the same for men and women and likewise for both conservatively and operatively treated patients From the point of view of age the series is not so very satisfactory

The injury occurred in 19 cases when the patient stumbled and fell once after a fall from a great height 7 times in traffic accidents once from a blow against the shoulder and once when lifting a weight In one case pain and loss of power occurred without injury When falling 14 patients had hit the shoulder against the ground and 4 had stopped their fall with the outstretched hand The remainder could not remember such details In 3 cases the humerus was dislocated

Subjective and objective symptoms The predominating subjective symptom was pain and reduced active mobility The majority of the patients complained of pain in the area of the deltoid and radiating pain along the outer aspect of the upper arm

Clinical examination revealed reduced abduction and flexion in about 4/5ths of the cases and in the remaining cases reduced strength of these movements (in two cases there was no mention of this however) (Figure 1)

Because of severe pain the corresponding passive movement was not measured in 13 cases It was normal in 11 cases 120–160 in 4 and less than 90 in 2

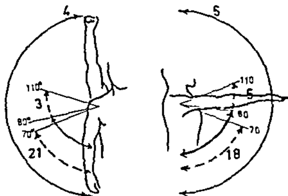


Figure 1 Schematic presentation of preoperative active abduction and flexion The figures indicate no of cases Unbroken curved line indicates extent of mobility common to all cases in the respective group a broken curved line indicating that in some cases the extent of mobility was less than in the best cases of the group

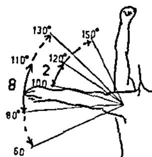


Figure 2 Schematic presentation of the zone within which pain was felt during abduction and adduction

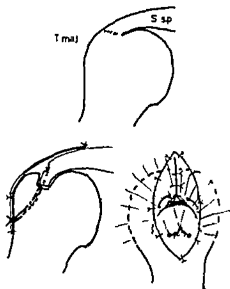


Figure 3 Schematic picture of the even transition from the greater tuberosity to an intact rotator cuff of the unevenness that occurs when the rupture margin is anchored in a groove in the bone and of a residual defect of the rotator cuff and of the method according to which the defect and the unevenness were covered with a fascia graft

Seven patients with active abduction of less than 80° were able to maintain the arm in abduction of about 120–150° when it had been passively raised

In 10 patients pain at the rim of the acromion occurred or was aggravated on abduction or adduction within the sectors 60–130 or 100–150 (Figure 2) In 9 of these crepitation over the acromion was simultaneously heard

The effect of local anaesthesia was investigated in 7 cases only In 6 of these cases active mobility improved in 3 cases from about 40° to normal abduction and flexion

Local tenderness to palpation over the greater tuberosity was a constant symptom Pronounced tenderness on the ventral side of the joint in one case pointed to rupture of the subscapularis and this was verified at operation Reduced strength of horizontal adduction gave reason to suspect such a rupture in another case Arthrography confirmed the presence of rupture but since operation was not carried out the exact position of the rupture could not be established A clear defect in the rotator cuff could only be palpated in one patient There was no mention of muscular atrophy

Diagnosis Twelve patients were examined by an orthopaedist 0-7 days after the injury 7 patients within 8-30 days 6 within 1-3 months and 5 within 4-14 months The diagnosis was made at the first clinical investigation in 23 cases and was subsequently verified by arthrography and at operation in 19 of these In 3 cases in which the primary diagnosis was dislocation of the humerus and in 4 which after unsuccessful conservative treatment without an exact diagnosis were referred to an orthopaedist the diagnosis was made after treatment for some time and in all cases it was verified as above

Treatment Operative treatment was suggested in all cases in which conservative treatment had been unsuccessful and primarily in all cases in which complete rupture had been demonstrated with certainty However operation within 15 days after the injury could only be carried out in 5 cases in the remaining cases there was an interval of 1 to 18 months (Figure 4) Operation was refused or considered contra indicated because of other diseases in 2 cases because of contracture in 1 marked muscular atrophy in 1 and insignificant clinical symptoms and arthrographic signs of a very small though complete rupture in 4 cases All operations were carried out by the present writer

As soon as rupture of the rotator cuff was suspected or demonstrated the arm was immobilized on an abduction splint until the pain had disappeared or until the patient was operated on An abduction splint was used to enable active mobilization

Operative method and findings Lexer s incision detaching the deltoid from the acromion was used in 19 cases and sabre-cut incision with osteotomy of the acromion according to Codman in 3 cases The former incision is often accompanied by irritating haemorrhages from small arteries along the clavicle and the acromion and does not allow full exposure of a retracted supraspinatus tendon Resection of the acromion as an additional measure was therefore necessary in 6 cases The sabre cut incision allows a wider field of view and causes less bleeding but the osteotomy requires osteosynthesis which may interfere with the intended early isometric muscle training

In 20 cases rupture of the supraspinatus tendon was observed In 13 of these cases the rupture also involved part or all of the infraspinatus tendon and in 2 cases also a part of the teres minor tendon and in 2 cases part of the sub capularis tendon Rupture of the subscapularis tendon alone occurred in 2 cases A slit from the transverse rupture along the ventral side of the supraspinatus tendon was observed in 4 cases and along its dorsal rim in 4 cases The proximal margin of the

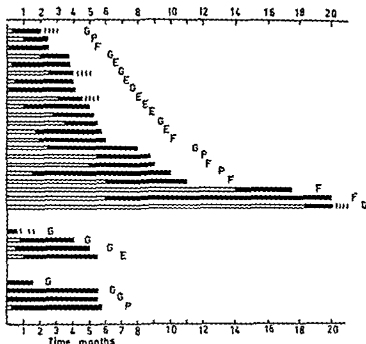


Figure 4. Diagram showing a) the interval between injury and operation and the beginning of mobilization treatment respectively (unfilled section of column) b) duration of sickleave from operation and the beginning of mobilization treatment respectively (filled section of column) c) total sick leave (whole column) and d) the result of treatment in each case (E excellent G good F fair P poor). The uppermost group of columns indicates operatively treated cases, the middle group conservatively treated and arthrographically verified cases and the lowest group clinically diagnosed and conservatively treated cases.

rupture was more or less retracted. In one case in which intense physical therapy had been given for 3 months and in which the rupture comprised the entire rotator cuff with the exception of the caudal part of the teres minor tendon, retraction was so marked that despite resection of the acromion it was impossible the reach the proximal margin of the rupture and reconstruction could not be carried out. (However it might have been possible to carry out reconstruction according to the method published four years later by *Debeyre et al.*, i.e. mobilization and lateral displacement of the supraspinatus muscle.)

In only one case did the rupture clearly comprise the area in which the blood supply is considered to be poorest, while in the remaining cases the distal stump of the tendon was shorter. This might have been the result of wear through friction against the acromion. In two cases loose cicatricial tissue was observed between the margins of the rupture

but is was so frail that it could hardly be expected to result in lasting healing *Kernwein et al* (4) state that they have never seen signs of spontaneous healing The biceps tendon which *Samilson et al* (12) often found at arthrography to be injured in connexion with rupture of the rotator cuff was completely torn in one and subluxated and partly torn in two cases

Reconstructive measures The margins of the rupture which were as a rule frayed and thickened were resected The proximal rim was fixed with two to four mersilene sutures carried through burr holes in the bone along a groove about 1/2 cm deep chiselled cranially and when necessary dorsally of the greater tuberosity The obliquely divided distal stump of the tendon was sutured with catgut over the proximal end in order to achieve as smooth a cuff surface as possible Longitudinal ruptures were closed with chromic catgut If retraction was too powerful to allow the entire proximal rupture margin to be fixed into the bone groove the remaining defect was closed as completely as possible with thin mersilene and chromic catgut I became increasingly convinced of the importance of reconstructing as smooth a surface as possible and of avoiding projection of the greater tuberosity over the cuff surface It was evident that a persistent opening between the joint capsule and the subacromial bursa would never heal spontaneously Therefore in one case in which the defect could not be completely closed I covered both the opening and the suture line with a free fascia lata graft The end result was good at any rate in this one case

Postoperative treatment After the operation the arm was immobilized on an abduction splint or in a thoracobrachial plaster cast Active deltoid exercises were commenced after 3–6 weeks in 4 cases preceded by isometric contraction exercises for 2 weeks As soon as the patient was able to lift his arm actively from the abduction splint (or the cut plaster cast) the splint was replaced by a wedge pillow and while active exercises were continued the abduction support was gradually reduced (Owing to a misunderstanding on the part of the staff immobilization was interrupted twice without preceding active abduction exercises Reoperation of one of these patients revealed that a new rupture had occurred proximally of the primary rupture and that this new rupture could no longer be closed) Active exercises were continued for 1½ to 3 months or until enough mobility and strength had been achieved that further improvement would occur at home and at work In one case this treatment was discontinued by the patient after 2 weeks

Pain which rendered mobilization more difficult occurred in 4 cases

at the greater tuberosity and in 1 at the bicipital sulcus In all but one case the pain disappeared after one or a few injections of Lidocain and hydrocortisone

Conservative treatment alone consisted of active mobilization preceded in acute cases by immobilization for 2–4 weeks on an abduction splint In one case with highly reduced passive mobility and arthrographically demonstrated completed rupture mobilization was carried out by force In 6 cases satisfactory mobility and freedom from pain were achieved after mobilization treatment of 2–4½ weeks while in one case the treament had to be continued for 2½ and in one for 4½ months

The period of sick leave in the operatively treated group was 2–20 months (average 7 8) and in the conservatively treated group 1½–6 months (average 4 6) Counted from the day of operation or the beginning of conservative treatment the incapacity for work lasted 2–6 months (average 4 4) in the first and 1½–5½ months (average 4 5) in the second group These figures do not include five housewives who partly resumed their housework during the period of immobilization

The results of treatment were estimated on the bases of a follow up examination carried out by myself in March 1965 when the period of observation for the operatively treated patients was 13–67 months (average 35) and for the conservatively treated patients 11–32 months (average 24) At examination I considered the patients own opinions as to whether they had become symptom free better or worse after the treatment and elicited information on spontaneous pain and pain on movement severity and localization movements provoking pain weakness stiffness and the effert of the symptoms on the capacity for work and on sleep This information has been collected in Table 1

The objective examination comprised measurement of active and passive mobility strength of movement crepitation and zones of painful movement tenderness on palpation and muscular atrophy (Table 2) The degree of active abduction in the frontal plane was measured as well as the maximal abduction achieved by free deviation from this plane In the same way flexion was measured in the sagittal plane and with free deviation from it Rotation movements were measured at three different positions i e with the upper arm adducted to the body abducted to 90 and flexed to 90 The degree of reduction of mobility was estimated by comparison with the contralateral healthy side A reduction of 0–15 of abduction and flexion and 0–10° of rotation was considered *normal* or *insignificant* 20–45 and 15–30 respectively

Table 1 Subjective improvement and signs in surgically and conservatively treated cases

		Surg	Cons
General impression	No complaints	6	1
	Improved	13	6
	No change or worse	3	1
Aching or pain on movement	None	6	2
	Only occasionally	11	4
	Continuously	12	1
	Continuously disturbing sleep	3	1
Localization of pain	At acromion or undetermined	4	2
	Ventral to the joint	13	2
	Along the brachium	5	4
Movement which provokes pain	Flexion	6	3
	Abduction	6	4
	Outward rotation	6	1
	Inward rotation	6	1
Stiffness		8	1
Weakness		7	1
Working capacity	(Almost) unchanged	14	7
	Has changed to lighter work	6	–
	Incapable of work	2	1

Pain provoked by movements was present in 10 surgically and 3 conservatively treated patients

Among these are 5 housewives and 2 old age pensioners

moderate and a higher reduction *considerable* A total deviation of 0-15 from the frontal and sagittal planes respectively at maximal abduction or flexion was considered *normal* or *insignificant* 30 was considered *moderate* and a higher degree *considerable* The strength was measured by the weight which the patient standing with his back against the wall and with elbow joint extended was able to lift to 90 at abduction and flexion respectively and comparing the result with the strength of the healthy arm The method is admittedly inexact and does not take into account the normal difference between the "good" hand and the "poorer hand nor of the fact that the significance of the difference between for instance 5 and 1 kg on the one hand and 15 and 11 kg on the other is not the same but nevertheless it was con

Table 2 Residual symptoms in surgically and conservatively treated cases
(For explanation see text)

Kind of treatment			Surgical	Conservative
Active flexion	Restriction	insignificant	13	6
		moderate	4	1
		considerable	5	1
	Deviation	insignificant	20	7
		moderate	2	1
Active abduction	Restriction	insignificant	9	6
		moderate	7	1
		considerable	6	1
	Deviation	insignificant	20	7
		moderate	2	1
Restriction of active inward rotation	In abduction	insignificant	10	3
		moderate	3	3
		considerable	9	2
	In flexion	insignificant	18	6
		moderate	2	1
		considerable	2	1
	In adduction	insignificant	22	8
		moderate	–	–
		considerable	–	–
Restriction of active outward rotation	In abduction	insignificant	12	4
		moderate	7	2
		considerable	3	2
	In flexion	insignificant	11	6
		moderate	6	2
		considerable	5	–
	In adduction	insignificant	11	4
		moderate	8	1
		considerable	3	3
Reduction of strength	In abduction	insignificant	10	3
		moderate	7	3
		considerable	5	2
	In flexion	insignificant	10	3
		moderate	7	3
		considerable	5	2
Painful zone by abduction adduction			2	–
Tenderness			2	–
Crepitation			3	1
Apparent muscular atrophy			3	
Abnormal humeroscapular rhythm			8	1

sidered adequate as a rough measure of the degree of reduction of strength

On the basis of subjective estimation and objective examination the results of treatment were estimated as follows

I *Excellent* No subjective complaints and capable of doing previous work No spontaneous pain only moderate pain if any on straining Extent and power of active abduction and flexion normal or insignificantly reduced Extent and power of rotation normal or insignificantly reduced or moderately to highly reduced in one direction only

II *Good* Subjectively improved and capable of former work Moderate pain on movement and after strain Active abduction and flexion normal or moderately reduced rotation only moderately reduced in all directions or considerably reduced in one direction

III *Fair* Subjectively improved incapable of previous work but capable of continuous easier work Moderate but persistent or frequent pain which occasionally disturbs sleep Either (1) moderate pain on all movements (2) active abduction and adduction highly reduced and one of the movements highly painful or its strength considerably reduced or (3) rotation highly reduced

IV *Poor* Subjectively unchanged or worse cannot work for his living Persistent pain which disturbs sleep the extent and strength of all movements reduced and painful

On the basis of these criteria the results of treatment were considered excellent or good in 13 of the cases treated operatively and in 7 treated conservatively and poor in 3 cases and 1 case respectively (Figure 4)

The four cases in which the result was poor will be briefly described and the probable reason for the failure stated

Case 1 65 year old woman operated one month after the injury When postoperative mobilization was commenced the abduction splint was removed by mistake and a new rupture occurred (see above) *Technical error and new rupture*

Case 21 A 53 year old man who had been treated elsewhere for over a year Large rupture which could not be closed at operation Postoperative pain which Lidocain hydrocortisone injections failed to alleviate Persistent pain pain on movement and stiffness Objectively moderate reduction of mobility painful zone and crepitation Arthrography showed persisting connexion between the joint capsule and the subacromial bursa *Technically unsatisfactory operative result*

Case 29 63 year-old man operated on 5 months after the injury Operative findings and primary operative result as in case 21 After 5 weeks immobilization in a thoracobrachial plaster cast the cast was removed by a colleague who had not been adequately informed without preceding deltoideus training Subjectively stiffness and pain on strain objectively all movements reduced *Technically unsatisfactory operative result and likewise after treatment probably a new rupture*

Case 24 52 year old man The injury was diagnosed as an incomplete rupture within 10 days of the injury Arthrography was planned but not carried out Mobilization which was commenced after 4 weeks on an abduction splint gave good results but when the patient returned to work as a dock worker the aching pain on movement and weakness returned Operation was suggested but refused *Probably underestimation of the extent of the injury Operative treatment might have given a better result*

DISCUSSION

Rupture of the rotator cuff seems to be more common than is generally assumed Particularly the possibility of rupture in connexion with dislocation of the humerus should be borne in mind *Samilson* (12) states that ruptures with dislocation are as a rule smaller than those without The fact that the two largest ruptures in my series were observed in cases of dislocation may have been due to enlargement of a primarily moderate rupture during intense active mobilization as described by *Campbell* (2) The fact that the retraction of the proximal margin of the rupture was assessed as considerable in only 1 of the 4 cases which were operated on within 15 days of the injury in 3 of the 6 operated on within 16–60 days in 4 of the 7 operated on within 2–6 months and in all patients operated on later than 6 months after the injury supports this assumption

Earlier reports that an intact supraspinatus tendon is not an absolute condition for active abduction were verified by the fact that in two patients with full active mobility (with reduced strength) rupture of the supraspinatus and part of the infraspinatus tendon was observed It is a common observation that rupture of the rotator cuff does not cause contracture In one of my arthrographically verified cases the contracture may have been present before the rupture occurred

An incision allowing adequate exposure and the possibility to reach even a far retracted rupture margin is necessary Not even resection of *the acromion close to the acromioclavicular joint or corresponding* osteotomy is always sufficient *Debeyre* s method is probably the best in inveterate cases

It is of great importance that the rotator cuff should be reconstructed so that its surface becomes whole and smooth and so that the greater tuberosity does not protrude In order to promote healing of a remaining defect of the rotator cuff *McLaughlin* (7) recommends resection of the joint cartilage beneath the defect so that the cuff heals by attaching to the bone However in such cases there is no hope of regaining full

mobility The good result which I achieved with a fascia lata graft encourages continued use of this method

In order to reduce the risk of interference between the greater tuberosity and the acromion McLaughlin recommends acromioplasty or division of the coracoacromial ligament I have not been able to observe any effect on the end results in 3 cases of acromioplasty or 6 cases of resection of the acromion except that the latter is cosmetically ungainly I have no experience of division of the ligament

For postoperative treatment *Campbell* (2) recommends balanced suspension until the wound has healed and then mobilization beginning with pendular movements with the arm hanging down *Wachsmuth* (13) *Adams* (1) and *Debeyre* (3) suggest an abduction splint or thoracobrachial plaster cast for a period of 6 to 8 weeks Active abduction within the first 6 to 8 weeks is not as a rule recommended In half my cases active abduction movements from the splint were started after as little as 3 to 4 weeks and in the remaining cases after 4 to 6 weeks The distribution of good and poor results is identical in the two groups It seems more important to ensure that the deltoid muscle is trained before the abduction splint is removed and that the degree of the abduction support is reduced gradually so that stretching of the rotator cuff can be avoided than to continue immobilization for a certain number of weeks

If the above case in which reconstruction could not be carried out and the 2 in which a new rupture (probably) occurred are excluded we find that when operation was performed within 15–60 days after the injury only excellent and good results were obtained while when operation was performed 6 months or more after the injury the result was never excellent and was good in only one case

Preoperative mobilization treatment for 0–8 weeks was not found to have any effect on the results of treatment but if treatment had been given for a longer period and the patient had tried to resume work before the operation the results tend to be poorer If there is marked muscular atrophy before operation postoperative mobilization is delayed The operation is technically easier to perform before the proximal margin of the rupture has retracted The total length of sick leave is shortened if preoperative mobilization treatment of long duration is not given

CONCLUSIONS

Direct comparison of the operatively and conservatively treated groups is impossible because of the difference in severity of the cases between

the two groups My experience with the first group has convinced me however that when the diagnosis of complete rupture of the rotator cuff with markedly reduced mobility reduced strength and pain on movement is certain, early operation is best Conservative treatment is justified when symptoms are insignificant when complete or almost complete active mobility is demonstrated after intra articular anaesthesia or when for other reasons operation or prolonged immobilization is contraindicated I do not consider an age of over 60 years a contra indication Co operation with a skilful and energetic physiotherapist is essential for good results

SUMMARY

22 cases of complete rupture of the rotator cuff were treated operatively and 8 (4 with arthrographically demonstrable complete but small rupture and 4 with clinically diagnosed incomplete rupture) conservatively

At operation I aimed at anchoring the cuff in a groove chiselled proximally to the greater tuberosity and at reconstructing as even and smooth a surface as possible In one case a fascia *lata* graft was used for this purpose

On the basis partly of the patient s subjective opinion and partly of objective clinical follow up examination the results were estimated as excellent or good in 13 operatively and in 7 conservatively treated cases Stress is laid on the importance of postoperative immobilization in abduction which is gradually reduced after the deltoid has been exercised

Observations at operation and the end results argue for early operative treatment of all cases with marked symptoms and without contra indications An age of over 60 years is not by itself a contraindication

RESUME

22 cas de rupture complete du *muscle rotateur de l épaule* ont ete traites chirurgicalement et 8 (parmi lesquels l arthrographie a decele une rupture complete mais petite dans 4 et le diagnostic clinique une rupture incomplete dans les autres 4) soumis a un traitement con servateur

A l operation j ai cherche a fixer le muscle dans un sillon cisele proximalement a la grosse tuberosite en reconstruisant une surface aussi lisse que possible Dans un cas une greffe de fascia lata a ete utilisee dans ce but

Partiellement sur la base de l opinion subjective des malades e partiellement sur celle de l examen clinique complementaire les resu tats ont ete juges excellents et bons dans 13 des cas operes et dans des cas soumis au traitement conservateur Les inconvenients provien nent de la duree de l immobilisation post opératoire en abduction ma ont ete progressivement reduits au fur et a mesure que le deltoide été entraine pour reprendre sa fonction

Les observations faites au cours de l operation et les resultats finau parlent en faveur d un traitement operatoire precoce de tous les cas pre sentant des symptomes marquees sans contre indication l age de 6 ans ne constitue pas comme tel une contre-indication

ZUSAMMENFASSUNG

22 Falle von vollständiger Ruptur der Rotatormanschette wurde operativ and 8 (4 mit arthrographisch nachweisbaren vollständiger aber kleinen Rupturen und 4 mit klinisch diagnostizierten unvollstän digen Rupturen) konservativ behandelt

Bei der Operation zielte ich darauf hin die Manschette in einer prox mal von dem Tuberculum majus ausgemeiselten Rinne zu veranker und bei der Rekonstruktion eine möglichst ebene und glatte Oberflach zu erhalten In einem Falle wurde ein Fascia lata Streifen zu dieser Zwecke verwendet

Teilweise auf Grund der subjektiven Meinung des Patienten un teilweise auf Grund klinischer objektiver Nachuntersuchung wurde die Ergebnisse als ausgezeichnet oder gut in 13 operative und 7 konser vativ behandelten Fällen angesehen Gewicht wird auf die postoperativ Ruhigstellung in Abduktion gelegt die stufenweise nach der Aufübun des M deltoideus vermindert wird

Beobachtungen wahrend der Operation und die Endergebnisse sprechen zu Gunsten einer frühzeitigen operativen Behandlung alle Falle mit ausgesprochenen Symptomen und ohne Kontraindikationer Ein Alter von über 60 Jahren ist an und fur sich keine Kontraindika tion

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ADDENDUM

Since this article was written I have operated on 5 further cases of arthrographically verified rupture of the rotator cuff 1 a 62 year old man and 4 45–53 year old women

In case 31 a 53 year old woman the reconstruction was performed one week after the injury through a short incision along the lateral border of the acromion The arm was postoperatively immobolised primarily on a wedge pillow later in a thoracobrachial plaster Owing to severe obscure pain the patient could not cooperate and a contracture developed Despite intense physiotherapy the end result 2 years after the operation was poor" (no pain but 50 per cent restriction of movement)

The other patients were operated by the method of Debeyre In cases 32 and 33 operated on 1¼ and 3 years after the injury respectively the supraspinatus muscle was advanced laterally and in case 32 the suture line in the cuff was covered with a fascia lata graft. At after examination of case 32 one year after the operation the result was excellent In case 33 and in cases 34 and 35 in which the reconstruction was performed within one month of the injury the intermediate result, as judged 7 6 and 5 months after the operation were fair excellent and good respectively

I have found the approach described by Debeyre superior to the other incisions because it allows free exposure and lateral advancement of the retracted supraspinatus muscle without which reconstruction would have been impossible in my cases 32 and 33

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BOECK'SCHE SARKOIDOSE (MORBUS SCHAUMANN) DER HANDMUSKULATUR

Von

GÖSTA FRYKMAN & LARS MÅRTENSON

Received 11 vi 67

Tuberkuloide Granulome wie sie beim *Morbus Schaumann* (*Boeck'sches Sarkoid*) bekannt sind aber eine andere Lokalisation als in Lymphknoten aufweisen haben verschiedene Autoren bereits früher beschrieben (*Licharew* 1908 *Mucha* und Mitarbeiter 1919 *Sundelin* 1925 *Jungling* 1928 *Bergel* und Mitarbeiter 1933 *Harrell* 1940 *Gravesen* 1942 *Oppenheim* und Mitarbeiter 1947 *Snorrason* 1947 *Bates* und Mitarbeiter 1948 *Krabbe* 1949 *Myers* und Mitarbeiter 1952 *Powell* 1953 *Danbolt* 1954 *Devic* und Mitarbeiter 1955 *Maurice* 1955 *Warburg* 1955 *Ammitzboll* 1956 *Bunnell* 1956 *McConkey* 1958 *Kock* 1959 *Brain* 1960 *Boyd* 1961 *Adams* und Mitarbeiter 1962)

Nicht ungewöhnlich sind derartige Veränderungen in den Lungen im Magen in der Leber der Milz dem Pankreas den Hoden der Parotis in den Tränendrüsen und in der Uvea Sogar im Hirn und im Myokard sind typische Granulome angetroffen worden In der Skelettmuskulatur kommen sie der Literatur entsprechend vorwiegend im Musculus gastrocnemius vor Im Skelett sind die Granulome praktisch immer in den Phalangen der Finger und der Zehen gelegen

Lokalisationen von tuberkuloiden Granulomen der Hand werden von *Howard* in Handbuch *Bunnells* als ungewöhnlich angegeben und treten nach dessen Angaben nur in Form von Hautinfiltration oder im Skelett der Phalangen auf Weder *Pael* (1939) noch *Howard Bunnell* (1956) beschreiben eine Lokalisation in der Handmuskulatur oder anderen Handweichteilen Ähnliche Angaben konnten auch bei anderen Verfassern die über Handtumoren geschrieben haben (*Mason* 1937 *Düben* 1960) nicht vorgefunden werden Einzig *Crompton* und Mitarbeiter haben 1961 zwei Fälle von tuberkuloiden Granulomen der Thenarmuskulatur beschrieben



Bild 1 Histologischen Preparat Boeck s Sarkoid in Handmuskulatur 30 × vergrössert

Bild 2 Histologischen Preparat Boeck s Sarkoid in Handmuskulatur 80 × vergrössert

Im Hinblick auf die seltenen Publikationen über in der Handmuskulatur lokalisierte Granulome der genannten Art halten es die Verfasser für angezeigt einen Fall mit Tumor in den Handweichteilen zu beschreiben bei welchem das rasche infiltrative Wachstum in einen der Interosseusmuskeln sowie der makroskopische Aspekt während der Operation den dringenden Verdacht auf Malignität nahelegte Die pathologisch histologische Diagnose ergab überraschenderweise tuberkuloide Strukturen wie beim *Morbus Schaumann* (*Boeckschess Sarkoid*)

Es handelte sich um einen 16 jährigen Knaben der wegen eines Tumors radial vom zweiten Metacarpophalangealgelenk der linken Hand zur Untersuchung kam Der Patient beobachtete diese Veränderung seit 1 Monaten weil sie ziemlich rasch an Grosse zunahmen und schmerzhaft waren Der Tumor war immer von elastischer Konsistenz Röntgenologisch zeigte das Handskelett keine pathologischen Veränderungen Klinisch konnte man radial vom Köpfchen des zweiten Metacarpale der linken Hand einen haselnussgrossen zweiteiligen

Tumor feststellen Die Veränderung war in einem kleinen Bereich an der Haut fixiert aber im übrigen gegenuber derselben frei beweglich In der Tiefe konnte eine ausgesprochene Fixation am ersten dorsalen Interosseusmuskel vorgefunden werden Der Tumor schien kaum unter dessen distalem Anteil zu liegen war aber doch nicht scharf begrenzt Präoperativ wurde uber die Diagnosen Xanthom oder Ganglion diskutiert Während der Operation konnte folgender Befund erhoben werden Die Tumorbildung bezog in einem umschriebenen Bereich die Haut mit ein wies aber zur Hauptsache eine Infiltration in den Musculus interosseus dorsalis I auf und war von bedeutend grosserer Ausdehnung als von aussen palpiert werden konnte Der vom Tumor befallene Muskel wurde in ganzer Ausdehnung entfernt Die exstirpierte Resistenz wies eine fleichige weissbraune Schnittfläche auf Makroskopisch fasste man den Verdacht auf Malignität und dachte an die Myofibrosarkom Pathologisch anatomisch fanden sich jedoch tuberkuloide Strukturen von der Art des *Morbus Schaumann* (*Boeck'sches Sarkoid*) Es lagen keine Anzeichen fur ein Neoplasma vor (*H Hansson*)

Diese pathologisch anatomische Diagnose war eine Überraschung und veranlasste eine erneute eingehende Aufnahme der Anamnese Hierbei ergab sich folgendes Ein älterer Bruder des Patienten war im vorangegangenen Herbst in der Klinik fur Lungenkranke unter der Diagnose *Sarkoid – Stadium I* behandelt worden Unser Patient selbst hatte keinerlei Erkrankung der Luftwege durchgemacht neuerdings ergab die Schirmbilduntersuchung der Lungen keinen pathologischen Befund Die Blutsenkung war bei Spitaleintritt 3 mm

Die durchgefuhrte Rontgenuntersuchung der Lungen ergab bilateral stark vergrosserte Hiluslymphknoten wie beim *Morbus Schaumann* (*Boeck'sches Sarkoid*) Die Tuberkulinproben gewohnlicher Verdünnung bis zu 1 mg waren negativ Den pathologisch histologischen Befund der Hand entsprechend wurde die fortsgesetzte periodische Kontrolle des Lungenbefundes angeordnet

MIKROSKOPIE

Grossere und kleinere runde beziehungsweise unregelmassig bandförmige Anhaufungen von Epiteloidzellen Diese liegen stellenweise ganz dicht, sind stellungweise durch mehr oder weniger reichliche Mengen von sklerotischem Bindegewebe ersichtlich. Disseminierte Epiteloidzellenhaufen finden sich auch im Fettgewebe Stellenweise sieht man solche eben interstitiell in der quergestreiften Muskulatur manche von diesen eindeutig destruiert Die meistenteils tuberkelzellahnlichen Epiteloidzellenhaufen enthalten nur an einer einzigen Stelle ein vielkernige Riesenzelle teils

mit kantengestellten Kernen teils mit ungleichmässig verteilten Kernen In angrenzenden Bindegewebsklerosierten Fettgewebe sieht man an einer vereinzelten Stelle Rundzelleninfiltrate

Nirgends werden kasige Nekrosen oder überhaupt Nekrosen gesehen

Keine Fremdkörper Bilder

Keine Zeichen auf Neoplasmata

P A D Tuberculoide Strukturen von einer Art wie sie bei dem Morbus Schaumann gesehen werden

Keine Zeichen auf Neoplasmata

(H Hansson)

DISKUSSION

Bei der Überprüfung der zugänglichen Literatur haben wir gefunden dass *früher nur zwei Fälle von tuberkuloiden Granulomen in der Hand*muskulatur (*Crompton* und Mitarbeiten 1961) beschrieben worden sind Bei dem von uns hier beschriebenen Fall konnten derartige Veränderungen isoliert in der Handmuskulatur festgestellt werden Sie erinnerten an ein Tumorgebilde Das klinische und das peroperative Bild liessen Malignität vermuten Es wurde der betroffene Handmuskel vollständig entfernt was den Wegfall einer für die Hand nicht unwichtigen Funktion mit sich führte

Irgendein Zweifel hinsichtlich der Diagnose des hier beschriebenen Fallen dürfte unter Berücksichtigung der übrigen klinischen Befunde kaum vorliegen

Mit Rücksichtsnahme auf die benigne Natur der Erkrankung dürfte bei Auftreten von Handmuskulatur Veränderungen von Typus *Schaumann* (*Boeck sches Sarkoid*) ein Eingriff geringeren Ausmasses als er im vorliegenden Falle ausgeführt wurde genügt haben Bei sicherem Ausschluss einer Malignität muss aber doch empfohlen werden den ganzen Muskel zu entfernen weil – wie im vorliegenden Fall – der funktionelle Ausfall doch relativ leicht kompensiert werden kann Man kann sich primär immerhin mit einer kleinen Probeexcision begnügen um zu der histologischen Diagnose zu gelangen und dadurch die aktuelle Muskelfunktion eventuell zu retten Die während der Ausheilung auftretenden fibrosen Neubildungen sind im allgemeinen nach den einschlägigen Literaturangaben zu schliessen nicht so hochgradig dass *dadurch eine bemerkenswerte Störung der Muskelfunktion befürchtet* werden musste

ZUSAMMENFASSSUNG

Es wird ein Fall von tuberkuloiden Granulom ohne Nekrose vom Typus der *Schaumann schen Erkrankung* (*Boeck sches Sarkoid*) beschrieben Die Lokalisation betraft die Handmuskulatur Die Veranderungen legten den Verdacht auf einen Tumor nahe dessen klinisches Bild und makroskopisches Aussehen an Malignität denken liess Die pathologisch anatomische Diagnose und das ubrige klinische Verhalten trugen zur Sicherung der Diagnose bei

RESUME

Description d un cas de granulome tuberculoide sans nécrose du type maladie de *Schaumann* (*sarcoide Boeck*) Par sa localisation il portait atteinte a la musculature de la main Par le tableau clinique et son aspect macroscopique de malignite il laissait soupçonner la presence d une tumeur Le diagnostic anatomo pathologique et les autres faits cliniques sont portes a l appui du diagnostic

SUMMARY

A case of tuberculoid granuloma without necroses i g Schaumanns disease or Boeck s sarcoide is described The granuloma was for the main part localized to the Musculus interosseus dorsalis I The clinical features and the macroscopical picture arouse suspicion of a malignant tumor The patho anatomical findings and the further clinical course disproved this suspicion

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From the Orthopaedic Hospital Aarhus Denmark
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SLIPPED UPPER FEMORAL EPIPHYSIS

Clinical Study on Aetiology

By

K Harry Sørensen

Received 13 xii 67

INTRODUCTION

The exact aetiology and pathogenesis of slipping of the upper femoral epiphysis have not yet been elucidated Generally the cause is assumed to be hormonal imbalance during puberty combined with mechanical strain on the epiphyseal cartilage

First an attempt will be made to sum up our present knowledge

1 *Sex and Age*

Slipping of the upper femoral epiphysis occurs around puberty most often between 13–17 years of age in boys and between 11 and 15 in girls Boys are more often affected *Jerre* (1950) found 83 per cent boys among 166 patients *Oram* (1952) 77 per cent among 147 and *Wilson et al* (1965) 71 per cent among 240

2 *Endocrine Disorders*

The occurrence of dyshormonal conditions in these patients may be explained in a very simplified way as follows If the pituitary gonadotrophin production starts too late or is reduced the production of sex hormone will be delayed and a condition reminiscent of adiposogenital dystrophy (Frolich s syndrome) results If the pituitary growth hormone production keeps high while that of the antagonistic sex hormones is normal pituitary giantism may occur Both conditions are transient

Harris (1950) administered growth hormone to castrated male and female rats and compared the histological changes in the epiphyseal

cartilage with an untreated series and a series treated only with oestrogen In the first mentioned group a widening of the layer of hypertrophied cartilage cells in the epiphyseal plate was noted This layer represents a mechanically weak zone which the slip always affects Thus an increased quantity of growth hormone will further weaken this zone

Slipping of the upper femoral epiphysis may occur in obese boys with a feminine distribution of fat and the characteristics of hypogonadism—but rarely in the form of a pure Frohch type— in rapidly growing thin in some cases very tall patients and in normal boys (*Key* 1926 *Shands* 1957 *Jackson Burrows* 1957 *Newman* 1958) The reported frequency varies widely in the first type for instance from 20 4 per cent (*Oram* 1952) to 65 per cent (*Howorth* 1957) *Howorth* found the height or weight to be significantly above average in 65 per cent half of whom were of the Frohch type *Jackson Burrows*, comparing height and weight with the normal values found endocrine defect to be probable in 42 per cent In another 12 per cent he found a moderate overweight which was unusual and 4 per cent of the patients were unusually tall *Wilson et al* (1965) reported obesity in 75 per cent and a Frohch like appearance in 22 per cent There are even transitions from the pure Frohch type to normality Hypogonadism cannot be assessed accurately and the diagnosis is often based upon an estimate *Jackson Burrows* reported that the menarche had occurred in only 2 of 38 girls before the slip was diagnosed

Skeletal development judging by X rays of the hands and wrists was normal in 29 of *Jackson Burrows* patients

Hormone analyses on the 24 hour urine (17 ketosteroids androgens oestrogens and gonadotrophin) have not revealed abnormalities except in a few instances (*Oram* 1952 *Jackson Burrows* 1957) Pituitary disorders and hypothalamic tumours have been reported as solitary cases in large series of patients (*Jerre* 1950 *Lofgren* 1953) and as an isolated case (*Bruns* 1960)

Jackson Burrows characterized 30 per cent of the patients as normal

3 *Poisoning*

Aminonitriles present int al in sweet peas (*Lathyrus odoratus*) may induce a typical histological appearance in animals (*Ponseti et al* 1954 *Ponseti* 1957) The toxicity is greatly increased by simultaneous administration of growth hormone and reduced by hypophysectomy (*Selye et al* 1957) *Ferguson & Howorth* (1931) diagnosed the majority

of their cases of slipped upper femoral epiphysis in July November viz 66 per cent *Andren & Borgstrom* (1959) diagnosed 54 per cent of their cases in June September They assumed that in the pastures the cows might ingest aminonitriles which were passed on to the patients through the milk

4 *Mechanical Factors*

Local mechanical factors must be decisive since slipping occurs in fact only in the upper femoral epiphysis while hormonal disturbances if any would be expected to affect all epiphyseal plates

a) *Side affected* Both hips are involved in 20–25 per cent (*Jerre* 1950 22 9 per cent of 166 pts *Oram* 1952 21 8 per cent of 147 *Wilson et al* 1965 25 per cent of 240 pts) but it is only in about half the cases that the slip occurs simultaneously on both sides *Unilateral* slipping affects the *left* hip significantly more often than the right viz in 73 4 per cent of 128 unilateral cases (*Jerre*) Correspondingly *Howorth* (1941) has reported 56 per cent of 113 *Oram* 65 5 per cent of 115 and *Wilson et al* 60 per cent of 180 cases *Jerre* found the left hip to be affected in 75 per cent of boys and in 64 per cent of girls *Oram* found the corresponding values to be 67 per cent and 58 per cent and *Jackson Burrows* 70 per cent and 50 per cent of 128 115 and 77 pts

b) *Trauma* Direct or indirect injuries are fairly uncommon in most cases mild and rarely of decisive importance *Oram* found single injuries in 27 8 per cent as a rule falls or kicks repeated injuries in 7 4 per cent but in 75 per cent of the patients the symptoms had started before the trauma occurred *Jackson Burrows* found relevant injuries prior to the onset of symptoms in 20 per cent simultaneously in 20 per cent and after in 12 per cent *Wilson et al* found injuries in 26 per cent

In slipping of the upper femoral epiphysis the femoral head gradually becomes displaced medially posteriorly and distally During walking the centre of gravity moves from side to side and this entails a shearing strain almost parallel to the epiphyseal plate This also happens when the leg is carried forward In games and physical exercises the left leg is the one which right handed persons use to take off

5 *Familial Occurrence*

The disease is rarely familial Among the siblings of the patients

Jerre found 2 per cent and *Oram* 3 per cent while *Wilson et al* found 5 per cent in the immediate family

PRESENT MATERIAL

An attempt was made to elucidate the aetiological problems by examining all young patients with slipped upper femoral epiphysis seen in the Orthopaedic Hospital Aarhus during the period 1957–1964 a total of *101 patients*

1 *Sex and Age*

The material comprises 76 boys and 25 girls (25 per cent) The sex ratio and age distribution correspond exactly to those found by others (cf Figure 2)

2 *Endocrine Disorders*

(a) *The height and weight were recorded in all cases when the slip* was diagnosed and at later follow up visits until cessation of growth Values for height and weight from the age of 7 were obtained from the school doctors health cards in 95 cases (6 cards had been destroyed)

Table 1 gives the weight and height at the time of diagnosis of the slip The weight is compared with the average weight for the height concerned in normals for each sex separately and the height is compared with the average height for the age concerned also for each sex separately (*Dossing* 1950) Both sexes show a marked tendency to obesity 26 boys (34 per cent) and 7 girls (28 per cent) weighed at least 15 per cent more than the average There was less variation in height In 89 per cent of the boys and in 84 per cent of the girls it was within 0 ± 9 per cent and none above 14 per cent i e slipping of the upper femoral epiphysis does not occur particularly in very tall patients *Figure 1 shows that very few were tall and thin This figure* illustrates the great variation in the weight with a tendency to obesity in both sexes

To assess abnormalities of growth all the height and weight measurements *from the age of 7 years are plotted on a special growth dia*gram (*Dossing* 1952) It applies to the 26 obese boys and 7 obese girls that they had been fat for many years (Table 2) Their obesity had been fairly constant they had not gained in connection with their disease and the consequently restricted physical activity The weight curve was normal for 30 boys and 7 girls with constant height weight

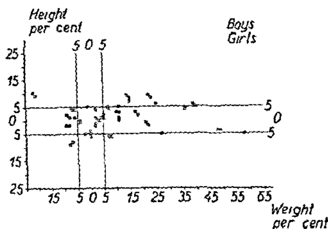


Figure 1 Height and weight of 101 patients when slipping of the upper femoral epiphysis was diagnosed in per cent of the average for normal children of the same age and sex

Table 1 Body weight in per cent of the average weight for the height concerned separately for each sex when slipping of the upper femoral epiphysis was diagnosed Height in per cent of the average height for the same age and sex (height measured at the same time as the weight) at the time of diagnosis

	Above average in %					[illegible]	*Below average in %*		
Per cent	25–63	20–24	15–19	10–14	5–9	+4 to –4	–(5–9)	–(10–14)	–(15–22)
Weight									
76 boys	16	4	6	11	6	22	7	1	3
25 girls	3	2	2	3	3	8	2		2
Height									
76 boys				6	15	44	9	1	1
25 girls				2	8	11	2		2

ratio and a normal weight from the age of 7 years until growth was completed 7 boys and 2 girls were slightly and constantly overweight (around 10 per cent) 2 boys and 3 girls slightly and constantly under weight In 7 boys and 4 girls the curve altered from being normal to showing after the slip was diagnosed a gain of about 10 per cent and thereafter a further gain A short lasting weight loss of about 5 kg continuing from a few months before until a few months after the slip had been diagnosed was observed in 15 boys and 4 girls (8 and 3 of the

Table 2 Obesity (at least 15 per cent in excess of the average weight) in 26 boys and 7 girls Duration (Broadly speaking unchanged height/weight ratio)

Obesity present prior to age (scale age in years)	4	5	6	7	8	9	10	11	12	13	1f years
26 boys			1	9	2	2	2	5	1	3	1
7 girls			1	1	2	1	1		1		
Duration of obesity so far at least (years)											
26 boys	1	6	5	3	2	3	1	2	3		
7 girls		2	1		1	2	1				

obese ones 2 and 1 of those showing about 10 per cent overweight and in 5 boys having an otherwise normal curve)

(b) *The adolescent growth spurt* The annual increment in height is normally increased in relation to the preceding years in boys from 12 to 15 and in girls from 10 to 13 but this adolescent growth spurt varies in degree and duration (*Tanner* 1962)

By plotting all the heights on graph paper the annual height increment was calculated and the adolescent growth spurt dated and compared with the age at which slipping of the upper femoral epiphysis was diagnosed In 75 patients (59 boys and 16 girls or 78 per cent and 64 per cent) the condition was diagnosed during the first middle or last part of the growth spurt viz in 6 15 and 38 boys and in 1 6 and 9 girls In 12 boys and 6 girls the growth spurt was indistinct and in 5 boys and 3 girls a few necessary measurements were lacking

(c) *Skeletal development* In all 101 cases the skeletal ige was determined on the basis of *Greulich & Pyle s* atlas (1950 1959) in 60 pts at the time of diagnosis and in 41 6 months to 3 years after In 2 growth had been completed In 67 pts 2–5 examinations were performed before completion of growth at average intervals of 14 months In 45 the result was the same every time in 20 one of the examinations differed by 1 standard deviation (S D) from the others and in only 2 pts did the skeletal age land in 3 groups *each differing by 1 S D from each other* In 44 pts the maximum difference between the determinations was 0–6 months in 15 it was 7–12 and in 9 pts 13–33 months As there was no tendency to normalization or increasing divergence but an even dispersion the mean value from several examinations was used as a

Table 3 Skeletal age for 99 patients with slipping of the upper femoral epiphysis stated as (1) deviation from chronological age in standard deviations (2) average deviation from the chronological age in months and the variation within the individual groups (3) skeletal age for overweight patients and for patients who had the lowest weight and the greatest height

Standard deviation	–(4–13)	–(3–4)	–(2–3)	–(1–2)	0 ± 1	+(1–2)
74 boys	0	5	12	26	30	1
25 girls	5	1	0	8	10	1
Percental distribution						
74 boys		17 = 23%		35%	40%	
25 girls	6 = 24%			32%	40%	
Average deviation (months)						
74 boys		42	29	18	–3	(14)
25 girls	58	24		12	–2	(10)
Range (months)						
74 boys		38–45	27–37	12–25	+6/–10	
25 girls	31–84			9–20	+3/–3	
Overweight (≧ 15%)						
26 boys		1	5	6	13	1
7 girls	1			1	5	
Total 33 % distribution (boys—girls)		21%		21%	55%	
Tall thin						
12 boys			3	6	3	
8 girls	1			4	3	
Total 20		20%		50%	30%	

basis According to *Greulich & Pyle* 1 S D for boys is 10–13 months and for girls 7–12 depending upon age

Table 3 gives the skeletal age in S D divergence from the chronological age Only 40 per cent of each sex showed less than 1 S D and only one of each sex + 1–2 S D In all the other patients there was a delay of at least 1 S D According to *Greulich & Pyle* 0 ± S D should normally include 90 per cent of the pts but in this material it included only 76 per cent In 23 there was a delay of at least 2 S D In Denmark where social conditions are favourable and medical prophylaxis extensive there is no basis for assuming that this might be due to nutritional

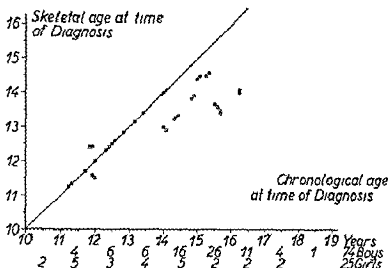


Figure 2 Chronological age of 99 patients when slipping of the upper femoral epiphysis was diagnosed and the skeletal age at that time The delay in skeletal development is clearly apparent as the same age units and the same starting point are used on the abscissa and ordinate so that all the values would be on the oblique 45 line if the skeletal age were normal

causes or diseases If anything there ought to be an influence in the positive direction

Figure 2 gives the chronological age at diagnosis and the skeletal age at this juncture providing a constant divergence during the subsequent 3 years for the 39 pts examined later This has been confirmed by the repeated examinations There is a marked dispersion of the chronological age (93 months) but far less (about 44 months) of skeletal age Thus the slipping of the epiphysis must arise during an interval which from the point of view of skeletal development is narrow At diagnosis the average skeletal age in boys was 13⁸ years (13 years 8 months) and in girls 12³ with a mean divergence of 10 and 16 months In other words slipping of the upper femoral epiphysis was diagnosed 16 and 9 months before closure of the epiphyseal lines normally starts in the hand (In the distal phalanges this closure starts in boys at 15⁰ years and in girls at 13⁰ years and continues rapidly in the remaining finger bones)

Figure 2 shows equally large age units on the abscissa and ordinate to illustrate clearly the delay in skeletal development Up to the age of 13½ years in boys and 12 years in girls the values are distributed uniformly around the 45 line but thereafter all values for girls and

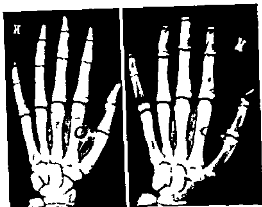


Figure 3 X rays of the hand and wrist of a boy aged 16^{2} years in whom the skeletal development is delayed by 3 years At the age of 17^{11} years the skeletal development is still 2^{7} years delayed being now 15^{4} years (closure of the epiphyseal plates in most distal phalanges) Slipping of the upper femoral epiphysis was diagnosed at the age of 16^{0} years (Case 67)

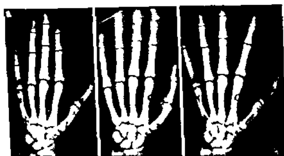


Figure 4 X rays of the hand and wrist of a boy at the ages of 17^{5} 18^{6} and 19^{5} years The delay in skeletal development amounts to 3^{0} 3^{6} and 3^{5} years respectively Slipping of the upper femoral epiphysis was diagnosed at 17^{5} years of age (Case 8)

all but 5 for boys are below The typical abnormality consists in failure of the epiphyseal plates to close This can be easily and definitely assessed radiographically (Figures 3 and 4) As is apparent from Table 3 the deviation from the chronological age is of no slight order of magnitude

Investigations of the skeletal age in 103 adolescent patients with Scheuermann's juvenile kyphosis from the same district had revealed no significant divergence from the normal values (*Sorensen* 1964)

The time of epiphyseal closure was controlled by comparing it with *Hansman's* findings (1962) A comparison could be performed in 50

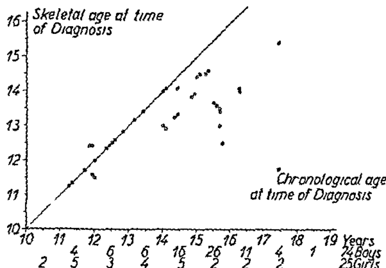


Figure 2 Chronological age of 99 patients when slipping of the upper femoral epiphysis was diagnosed and the skeletal age at that time The delay in skeletal development is clearly apparent as the same age units and the same starting point are used on the abscissa and ordinate so that all the values would be on the oblique 45 line if the skeletal age were normal

causes or diseases If anything there ought to be an influence in the positive direction

Figure 2 gives the chronological age at diagnosis and the skeletal age at this juncture providing a constant divergence during the subsequent 3 years for the 39 pts examined later This has been confirmed by the repeated examinations There is a marked dispersion of the chronological age (93 months) but far less (about 44 months) of skeletal age Thus the slipping of the epiphysis must arise during an interval which from the point of view of skeletal development is narrow At diagnosis the average skeletal age in boys was 13^8 years (13 years 8 months) and in girls 12^3 with a mean divergence of 10 and 16 months In other words slipping of the upper femoral epiphysis was diagnosed 16 and 9 months before closure of the epiphyseal lines normally starts in the hand (In the distal phalanges this closure starts in boys at 15^0 years and in girls at 13^0 years and continues rapidly in the remaining finger bones)

Figure 2 shows equally large age units on the abscissa and ordinate to illustrate clearly the delay in skeletal development Up to the age of 13½ years in boys and 12 years in girls the values are distributed uniformly around the 45 line but thereafter all values for girls and

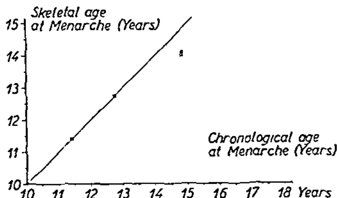


Figure 5 Age at menarche for 19 girls and skeletal age at the same juncture Same age units as used in Figure 2

boys the androgen fraction was low averaging 18 per cent of the total value as compared with 28 per cent in the other 9 The skeletal age in 15 of the 17 boys was delayed by at least 1 S D average 24 months Of these 17 boys 8 were obese and 3 were thin In 7 pts under 15 years of age the total 17 KS were presumably low but for this age no normal values have been reported Hypogonadism may have been present in these 17 boys and possibly in others too Correspondingly 5 girls over 15 years of age had low total 17 KS including 2 with a low androgen fraction One was obese The skeletal age was delayed by an average of 42 months and in all cases by at least 1 S D

The 24 hour output of *dehydroisoandrosterone* which is a pure adrenal metabolite was found to be constant in both sexes and normal from the age of 12 to 18 years

The amount of *androgen* in the 24 hour urine in the 12–17 year group was found to be elevated for all age groups in both sexes and androgen was demonstrated 2 years before the normal time in the girls The mean values were elevated from 15 per cent up to 3 times the value normal for the age and also in a somewhat jumpy way with increasing age If the assessment is based upon skeletal age the values are even more elevated By this analytical method at least 90 per cent of the urinary androgen activity ought to be demonstrated An increased influence of androgen upon the epiphyseal plates ought to tend to earlier closure but we found the reverse In recent years however it has become a well known clinical experience that determination of the 17 KS excretion and fractionation is a poor and insufficient parameter

of androgen status (*Lindholm* 1967) New improved analytical methods have been developed As the named investigations are from 1957–1964 nothing definite can be concluded from the analyses

(f) *Special abnormalities* (case reports) (1) A girl with slipping of the right upper femoral epiphysis aged 17^{3} years Skeletal age —7^{0} years At the age of 20 she was found to have calcific deposits around the sella turcica which was quite small No gonadotrophin in the 24 hour urine very low oestrogen values genitalia hypoplastic but ovaries seen in an appendicectomy At the age of 24^{7} years her skeletal age was —11^{3} years no menarche Diagnosis Primary hypoplasia of the pituitary gland

(2) A girl with slipped right upper femoral epiphysis age 17^{5} years skeletal age —5 years At 21 years of age the sella turcica was found to be normal the 17-KS were low (1 6 mg/24 hours) no oestrogens or gonadotrophin genitalia very hypoplastic no menarche skeletal age —5^{8} years sex chromatin female B M R +20 per cent Diagnosis ?Absence of ovaries

(3) A girl with slipped left upper femoral epiphysis age 16^{11} years skeletal age —4^{6} years height/weight 135 cm/43 kg (—17/+40 per cent) At 17^{10} years Low 17 KS (3 7 mg/24 hours) no oestrogen demonstrated gonadotrophin normal At 19^{1} years the menarche had not yet occurred skeletal age —5^{10} years height/weight 139/50 Diagnosis Dwarfism (primary ?)

(4) A boy with slipped upper femoral epiphyses on both sides age 16^{10} years skeletal age —2^{10} years height/weight 139 cm/44 kg (—19 per cent/—38 per cent) hypogenital reduced gonadotrophin (below 3 mouse units/24 hours) very low 17 KS (1 3 mg/24 hours) and no increase following administration of metopirone B M R — 16 per cent At 18^{3} years Skeletal age —3^{6} years height/weight increased to 149/57 after treatment with gonadotrophin thyroid and cortisone Diagnosis Pituitary dwarfism

Thyroid diseases were not present among the patients The paternal aunts of 3 boys and of 2 girls had been operated upon for goitre probably toxic

Diabetes mellitus was present in the mother of one girl Otherwise there were no cases of diabetes in the families (pts siblings or parents)

3 *Poisoning*

The symptoms had been present for an average of 5 months for an equal length of time in both sexes when slipping of the femoral epiphysis was diagnosed ranging from 1 day to more than a year Table 4 lists the time of the year at which the symptoms started in 61 pts with *a history shorter than 6 months in whom this juncture could be established* with most accuracy Moreover it gives the time at which the diagnosis was made The symptoms set in in June September in 36 per cent of the boys and in 59 per cent of the girls (43 per cent of the total series) During the same period the diagnosis was made in 33 per cent of the boys and 48 per cent of the girls (37 per cent of the total series) The month of birth was June–September for 33 per cent of the patients and might just as well be used as a basis when considering how narrow is the skeletal age interval in which the disease starts

Table 4 I Time of year at which the symptoms of slipped upper femoral epiphysis started (Length of history 0–25 weeks) II Time of year at which the diagnosis was made III Birth month

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
I												
44 boys	3	2	1	4	2	1	7	2	6	2	6	8
17 girls	1	1		1	1	3	1	4	2	2	1	
II												
76 boys	7	9	5	8	5	7	1	6	11	5	6	6
25 girls	2	2	1	1	2		1	5	6	3	2	
III												
76 boys	10	8	4	9	8	12	5	7	2	2	4	5
25 girls	2	2	3		3		3	1	3	4	1	3

The period July–November does not show any major accumulation The diagnosis was made in 38 per cent of the boys and 68 per cent of the girls 26 per cent and 48 per cent were born during these months

During the months July December the symptoms had started in 70 per cent of the boys and 59 per cent of the girls having a history shorter than 6 months (total series 63 per cent boys and 50 per cent girls) In 46 per cent of the boys and 68 per cent of the girls the diagnosis was made and 33 per cent and 60 per cent were born during these months

firmed the reported findings in respect to the age and sex distribution the disease occurring around puberty and the ratio boys/girls being 75 per cent/25 per cent Bilateral involvement was found in 25 per cent and a left sided preponderance in the unilateral cases among boys (66 per cent) but not among girls Familial occurrence is rare (3 per cent) 25 per cent had a history of initial trauma but usually too mild to have caused the slip

There is a very marked variation in body weight with a pronounced tendency to obesity but with an even transition from normal weight to marked overweight and with an even distribution whereas height was normal with but little dispersion Height and weight measurements from the age of 7 years until the cessation of growth showed for all the patients and in particular for the overweight ones that broadly speaking the height/weight ratio remained constant It is demonstrated that the slipping of the epiphysis occurs during the adolescent growth spurt

Determination of skeletal age on the entire material in most cases repeatedly revealed a significant delay in skeletal development alike in both sexes the closure of the epiphyseal plates being delayed Slipping of the upper femoral epiphysis occurs during a narrow skeletal age interval and in girls almost exclusively prior to the menarche The correlation between the menarche and skeletal development is confirmed

Hormone analyses including fractionated 17 ketosteroid determination on 24 hour urines gave no aetiological or pathogenetic information

The tendency to obesity and delay of epiphyseal closure entails an increased stress on the epiphyseal plate at the upper end of the femur at the very age during which the young people are keen on games and at which there is a considerable gain in body weight

RESUME

Apres un court compte rendu de la litterature sur les connaissance que nous avons actuellement de l'etiologie et de la pathogenese de l'epiphysiolyse de la tete femorale il est analysé un materiel de 101 jeunes malades La litterature confirme le répartition selon l'age et le sexe On constate en effet que l'epiphysiolyse de la tete femorale se manifeste a l'age de la puberte dans 75 pour cent des cas chez les garçons et dans 25 pour cent chez les filles Elle est bilaterale dans 25 pour cent

des cas avec dans les cas unilateraux une preponderance pour le cote gauche chez les garçons (66 peur cent) mais non chez les filles Il est rare que maladie ait un caractere familial (3 pour cent) Chez un quart des malades on trouve un trauma initial mais souvent si leger qu il ne peut pas etre a l origine de la maladie

On constate une tres grande dispersion du poids avec une tendance marquée a l adipose avec transition reguliere du poids normal au poids tres eleve et une repartition egale des masses graisseuses tandis que la hauteur de la taille est generalement normale Le controle de la hauteur de la taille et du poids a partir de l age de 7 ans et jusqu a la fin de la croissance montre bien pour tous les malades et en particulier pour ceux qui ont un poids trop eleve que le rapport entre la hauteur et le poids est dans l ensemble reste constant Il est demontre que l epiphysiolyse apparait dans la derniere phase de la croissance de l adolescent

La determination de l age des os effectuee chez tous les sujets pour la plupart a plusieurs reprises montre qu il y a un retard marque dans le developpement des os qui est le meme pour les deux sexes le fermeture des plaques epiphysaires etant retardee En ce qui concerne l age des os la maladie se manifeste dans un intervalle de temps limite et chez les filles pour ainsi dire exclusivement avant la premiere menstruation Un rapport entre la menstruation et le developpement des os est confirme Des analyses d hormones avec la determination au 17 ketosteroid fractionne de l urine de 24 heures n a pas donne de nouveaux renseignements susceptibles d elucider l etiologie et la pathogenese

La tendance a l adipose et le retardement de la fermeture epiphysaire entrainent une pression accrue sur la plaque epiphysaire de l extremite femorale superieure justement a l age ou il est courant de pratiquer du sport et ou le poids du corps augmente considerablement

ZUSAMMENFASSUNG

Nach einer kurzen Litteraturubersicht uber unser gegenwartiges Wissen der Äthiologie und Pathogenese der Epiphyseolysis capitis femoris (ecf) wird ein Material von 101 jungen Patienten (ptt) analysiert und die Litteraturangaben hinsichtlich des Alters und der Geschlechtsverteilung werden bestätigt indem ecf um die Pubertät in 75 Prozent der Falle bei Knaben und in 25 Prozent bei Mädchen auftrat Ecf tritt beiderseitig in 25 Prozent mit linksseitigem Übergewicht in den seitigen Fällen bei Knaben auf (66 Prozent) aber nicht bei Mä

Familiäres Auftreten ist selten (3 Prozent) Bei ¼ findet man Traumen die jedoch oft so leicht sind dass sie nicht als Ursache angesehen werden können

Man weist eine sehr starke Gewichtszunahme mit ausgesprochener Neigung zur Adipositas aber mitgleichmässigem Übergang von normalen Gewicht zu schwerem Übergewicht und mit gleichmässiger Verteilung nach wogegen die Grösse normal, mit nur geringer Zunahme verbleibt Grösse und Gewichtmessungen vom 7 Jahrs Alter bis zum Wachstumsabschluss zeigen für alle ptt und besonders für die Übergewichtigen dass das Grösse Gewichtsverhältnis im grossen ganzen konstant war Man weist nach dass die ecf sich während des beschleunigten *adolescenten* Wachtums entwickelt

Knochenalterbestimmungen im ganzen Materiale bei den meisten mehrfach ausgeführt, haben gezeigt dass eine bezeichnende Verzögerung der Knochenentwicklung besteht gleich bei beiden Geschlechtern indem die Schliessung der Epiphysenscheiben verspätet ist Ecf tritt in einem knochenaltermässig knappen Zeitraum auf und bei Mädchen beinahe ausschliesslich vor der Menarche Die Beziehung zwischen der Menarche und der Knochenentwicklung wird bekräftet

Hormonbestimmungen mit fraktionierter 17 ketosteroidbestimmung des Tagurins haben keine neuen Aufklärungen gegeben die zur Klarlegung der Athiologie und Pathogenese beitragen könnten

Die Neigung zur Fettleibigkeit und die Verspätung Epiphysenschlusses führten zur vermehrten Belastung der Epiphysenscheibe am obersten Femurende gerade in einem Alter wo Sportausübung sehr ausgebreitet ist und in dem das Körpergewicht bedeutend zunimmt

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OPERATIVE TREATMENT OF OSTEOARTHRITIS OF THE DYSPLASTIC HIP JOINT

By

TETSUO ITO MOTOO YOKOSAKI & MASAKI NAKAMASU

Received 27 II 67

McMurray (1935) advocated his oblique intertrochanteric osteotomy with medial displacement of the distal fragment for osteoarthritis of the hip In 1950 *Pauwels* introduced varus osteotomy without displacement an operation which has been used chiefly on young adults with painful dysplastic hips His procedure is based on the principle of an increase in weight transmitting areas of the articular surfaces With his method he demonstrated that osteoarthritic hip joints have a remarkable regenerative power regardless of the stage of the disease or the age of the patient *Voss* temporary hanging hip operation has also secured a place in the treatment of degenerative hip disease It was proved that his operation also relieves pain and promotes regeneration of the affected joint It is frequently used in patients too old to tolerate such major operations as arthrodesis and osteotomy Furthermore in cases with medial osteophyte formation *Pauwels* tried valgus osteotomy combined with release of the muscles about the hip to increase the weight transmitting areas of the articular surfaces In addition he theoretically demonstrated the following three factors which improve the degenerative changes in the joint

1 Reduction of intermittent pressure in the hip during walking
2 Reduction of pressure caused by muscle tension
3 Increase in the size of the areas of the joint surfaces on which these forces act

Furthermore *Pauwels* demonstrated the mechanism of osteotomies which he compared with a release operation in overcoming vicious muscle pull at the hip (Figures 1 and 2) In his opinion the varus

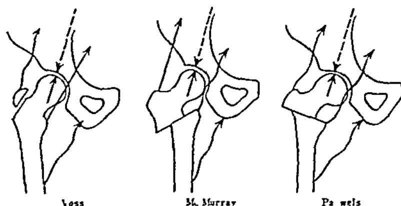


Figure 1 Drawings adopted from Pauwels illustrate the muscles that are relaxed to relieve pressure on the hip by the Voss' original hanging hip operation by the McMurray's osteotomy and by the Pauwels varus osteotomy

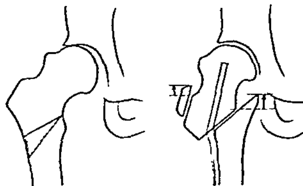


Figure 2 Pauwels' valgus osteotomy accompanied by the muscle release operation

osteotomy meets three demands for improvement of the disease and valgus osteotomy combined with release operation meets two demands McMurray's displacement osteotomy also reduces the load acting on the joint like Voss' hanging hip procedure

An incongruity between the articular surfaces is one important etiological factor of osteoarthritis of the hip It may be due to dysplasia of the femoral head or acetabulum or both with or without coexisting subluxation of the joint It may be acquired for instance as a sequela of coxa plana and it may also be traumatic Another group is made up of senile osteoarthritis whose pathogenesis is not yet properly



Figure 3 Roentgenogram showing resection of the outer edge of the acetabulum in a dog

understood Follow up studies of the clinical process in a large series of osteoarthritis of the hip suggest that in Japan the vast majority of cases is caused by acetabular dysplasia We therefore undertook an experimental study of the biomechanism responsible for the development of osteoarthritis of the hip in dogs in which the superior outer edge of the acetabulum was resected On the basis of the results of clinical studies reported by many authors mentioned above and observations made in our clinical and experimental studies we were able to lay down basic principles of treatment of osteoarthritis of the hip with incongruity Furthermore on the basis of these principles various operative procedures were performed in 50 cases of osteoarthritis of the hip The results of our studies are reported below



Figure 4 Pathological changes in the femoral head in a dog four months after resection of the outer edge of the acetabulum The mushroom shaped femoral head is seen in the gross specimen (A) roentgenogram (B) and histological section (C) The histological picture (C) shows slight abrasion of the central part of the articular cartilage and replacement of the red marrow with fatty tissue accompanied by formation of osteophyte around the head



Figure 5 Pathological changes in the femoral head in a dog five months after resection of the outer edge of the acetabulum A mushroom shaped femoral head is seen in the gross specimen (A) roentgenogram (B) and histological section (C) The histological picture shows almost complete loss of the articular cartilage destruction of the bony trabeculae at the top of the head accompanied by thickening of the remaining trabeculae and formation of a large osteophyte around the head (C) In the lateral non pressure part of the head there is a region with thin trabeculae seen as a localized radio translucent area in the roentgenogram (B)

Experimental and Clinical Studies on the Development of Osteoarthritis in the Hip with a Defect of the Outer Superior Acetabular Roof

When the outer superior edge of the acetabulum was resected in adult dogs (Figure 3) degenerative arthritic changes developed within five to six months after operation The results of this experiment are summarized as follows

1 Abrasion of the central localized part of the articular surfaces due to abnormal friction was the first pathological change which appeared in the course of the experiment (Figures 4 A 5 A and 6 A)

2 With time osteophytes formed around the femoral head which then migrated from the center of the acetabulum (Figures 4 and 5)

3 On histological examination of the femoral head within one to two months after operation almost all the animals showed destruction or loss of the central small localized articular surface and thinning or loss of the trabeculae in the upper part accompanied by replacement of red marrow with fatty tissue (Figure 4 C) These pathological changes were followed by reactive proliferation of the cartilage cells in the articular cartilage and reactive thickening of the remaining trabeculae and new bone formation around the head (Figure 5 C) In typical cases five to six months after operation marked thinning of the trabeculae or the formation of cysts was found in the lateral part



Figure 6. Pathological changes in the femoral head in a dog six months after resection of the outer edge of the acetabulum. Formation of a large cyst is found in the lateral part of the femoral head which is subject to least pressure.



Figure 7. Roentgenograms showing rapid upward migration of the femoral head in the dysplastic hip with osteoarthritis. Figure 7 A in November 1964. Figure 7 B May 1965. The upward migration of the femoral head was accompanied by an enlargement of the medial osteophyte indicated by arrows.

of the head which was subjected to least pressure (Figures 5 C and 6 C). Similar pathological findings are also often made in human osteoarthritis of the hip. Two roentgenograms made at an interval of six months in a case of osteoarthritis of the hip with acetabular dysplasia are reproduced in Figures 7 A and B. Figure 7 A shows acetabular



Figure 8 Dysplastic hip with degenerative arthritis Several cysts are arranged in the oblique equatorial plane of the femoral head where shearing stress is supposed to act

dysplasia narrowing of the cartilage space and slight upward migration of the femoral head with formation of lateral cysts and a small medial osteophyte The roentgenogram (Figure 7 B) made six months later revealed rapid progress of upward migration of the femoral head followed by enlargement of the medial osteophyte Figure 8 shows a moderately advanced case of osteoarthritis of the right hip In this figure the mushroom shaped femoral head contains several cysts arranged in the oblique equatorial plane These findings suggest that a shearing stress as indicated by arrows continuously acts on the medial longitudinal weight bearing trabeculae in the femoral head resulting in their gradual destruction followed by reactive formation of osteophytes around the femoral head and upward migration of the femoral head In all cases with acetabular dysplasia pressure on the femoral head caused by muscle tension is transmitted concentrically to the small localized contact area of the femoral articular surface and may cause a continuous shearing stress on the medial longitudinal trabeculae of the femoral head resulting in their destruction Moreover during walking an instability of the hip joint causes abnormal

friction between the two small articular surfaces which may exert an extremely strong intermittent shearing stress on the medial longitudinal trabeculae in the femoral head All these abnormal mechanical factors may cooperate in the causation of the complicated degenerative changes in the hip joint

Trabecular Architecture of the Upper End of the Femur

The results of experimental and clinical studies on the development of osteoarthritis of the hip prompted the authors to attempt a study on the trabecular architecture of the upper end of the femur For this study thirty specimens of the normal human femur were sliced parallel in the frontal plane In these specimens the angle which the medial longitudinal weight bearing trabecula passing through the center of the femoral head forms with the longitudinal axis of the shaft was measured roentgenologically (Figure 9) It was found to be about 22 Further photoclastic experiments were carried out to elucidate the function of the transverse trabeculae arising from the lateral cortex below the greater trochanter and running to the femoral head (Figures 10 A and B) The tensile force in the upper part of the femoral neck induced by a vertical load on the femoral head as indicated by the arrow in Figure 10 A is eliminated by a load acting on the greater trochanter in the direction of the gluteal muscle which is less than one half of the load on the femoral head as shown in Figure 10 B In



Figure 9 Roentgenogram showing the trabecular architecture of the upper end of the femur The medial longitudinal trabecula which bear the body weight form an angle of approximately 22 degrees with the longitudinal axis of the shaft

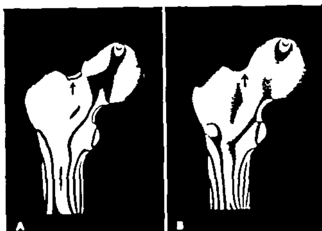


Figure 10 Photoelastic study on the mechanical stress induced by loads acting on the upper part of the femur A tensile force at the upper part of the femoral neck induced by a vertical load acting on the femoral head as indicated by the arrow in Figure 10 A is eliminated by a load acting on the greater trochanter in the direction of the gluteal muscles which is less than one half of the load on the femoral head as shown in Figure 10 B

the normal hip the pressure of more than one half of the load on the femoral head is thought to act on the greater trochanter in the direction of the gluteal muscle while standing and walking It was proved by these photoelastic experiments that the transverse trabeculae also bear the transverse pressure produced by the abductor muscles rotator muscles tensor fasciae latae muscle and also adductor muscles which presses the femoral head against the acetabulum From these facts it is evident that the trabecular architecture of the upper end of the femur is also constructed on the basis of the following general principles of bone formation The line of the bony trabeculae corresponds to the line of maximal pressure Further the trabeculae are thickest and most closely packed where the stress is greatest The medial longitudinal trabeculae are thickest and most numerous and bear the greater part of the load on the joint On the other hand these long trabeculae are thought to offer the least resistance to shearing stress It would therefore appear that in the hip with acetabular dysplasia the articular surfaces are worn down by friction and the medial longitudinal trabeculae are broken by shearing stress resulting in destructive changes combined with reactive new bone formation around the femoral head and upward migration of the femoral head

Principles of Operative Treatment for Osteoarthritis of the Hip with Incongruity between the Articular Surfaces

On theoretical grounds the results of the studies mentioned above warrant the following principles of operation for osteoarthritis of the hip secondary to acetabular dysplasia (Figures 11-A, B, C and D).

1. In early osteoarthritis of the hip with marked acetabular dysplasia in which the articular cartilage is well preserved, the affected joint is reconstructed into a mechanically stable condition by a shelf operation combined with a muscle release operation around the hip (Figures 11 A and B). In this case innominate osteotomy may also be indicated on the basis of the same principle.

2. In cases with acetabular dysplasia and deformities of the femoral neck or upward migration of the femoral head from the center of the acetabulum combined with formation of medial osteophyte, the affected joint is reconstructed into the mechanically stable condition by combination of the shelf operation, varisation or valgisation of the femoral neck and medial displacement of the shaft (Figures 11 C and D). Parti

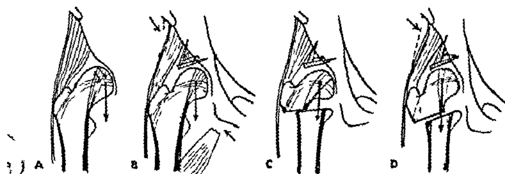


Figure 11. Diagrams showing principles of operative procedures for osteoarthritis of the hip secondary to acetabular dysplasia. In the hip with acetabular dysplasia a load on the femoral head is transmitted through a point medial to the center of femoral head. The small localized articular surfaces are subjected to a strong friction and the medial longitudinal trabeculae to a shearing stress (A). By shelf operation these abnormal mechanical stresses are eliminated and the weight transmitting areas of the articular surfaces increase in size. Moreover the joint is decompressed by release of the muscles around the hip (B). Furthermore, as shown in C and D, the joint is reconstructed into the mechanically stable condition by various combinations of the shelf operation, varisation (C) or valgisation (D) of the femoral neck, medial displacement of the shaft and release of the muscles about the hip. Particularly by valgisation of the femoral neck the medial longitudinal trabeculae are made erect, resulting in elimination of the shearing stress acting on them.

cularly as seen in Figure 11 D when the femoral neck is placed in a valgus position by osteotomy the medial longitudinal trabeculae are made erect and in consequence they are completely released from the shearing stress This procedure should be followed by a muscle release procedure to reduce the excessive pressure on the joint Bone grafting in a large cyst promotes repair

Technique of the Shelf Operation and Release of the Muscle about the Hip

The shelf operation should be performed with an exact technique The Smith Petersen anterior iliofemoral skin incision is usually used The attachments of the gluteus medius and minimus muscle and tensor fasciae latae muscle are severed from the iliac crest and the gluteal muscles are subperiosteally stripped from the external surface of the ilium The reflected tendon of the rectus femoris muscle is also dissected Then the joint capsule is opened and the site where the shelf is to be created is determined under direct vision Next two bone plates and several small bone chips are taken from the outer table of the ilium A bone plate concave in shape and of size adequate to cover the portion of the femoral head which projects beyond the acetabulum is inserted deeply into the acetabular rim in a semicircular line conforming to the natural curve of the acetabulum Then the second bone plate is bridged between the first bone plate and the outer table of the ilium Several bone chips are placed in the triangular space surrounded by the two bone plates and the ilium The abductor muscles and tensor fasciae latae muscle are reattached to the ilium in a relaxed state Subsequently open adductor tenotomy is carried out No plaster cast is applied After operation skin traction of the involved leg up to four kilograms is maintained for four weeks Thereafter the patient is encouraged to perform exercises of the affected limb and is allowed up on crutches

MATERIALS

Since 19 9 50 osteoarthritic hips of 48 patients (45 females and 3 males) aged 19 to 57 years (mean 35) have been surgicall treated in accordance with the principles described in the foregoing In this serie the shelf operation combined with release of the muscles about the hip was performed in 38 hips and various combinations of shelf operation varisation or valgisation of the femoral neck and medial displacement of the femoral shaft by intertrochanteric osteotomy and release of the muscles about the hip were carried out in 12 hips

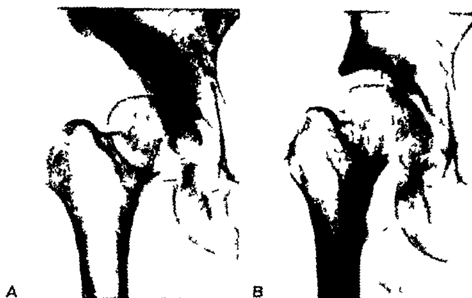


Figure 12 Case 1 A an early stage of osteoarthritis of the hip with formation of cyst in the dysplastic acetabular roof B three years after the shelf operation combined with release of the muscles around the hip

RESULTS

The patients were followed up for two to seven years (average three and a half years) So far good results have been obtained in all cases In most cases pain of the affected hip disappeared two to six months after operation However limp due to weakness of the muscles about the hip persisted for more than six months after the operation Roentgenographically the shelf created was replaced by new bone within six months after operation The degenerative changes in the affected joint were gradually repaired in the course of one to two years In advanced cases in which the shelf operation was carried out in combination with medial displacement of the femoral shaft and varisation or valgisation of the femoral neck numerous thickened vertical longitudinal trabeculae were formed in the femoral head and the cartilage space also increased in width The range of motion of the involved hip decreased to some degree in some cases but this was of little concern as the patients were relieved of pain

CASE REPORT

1 Shelf operation combined with release of the muscles about the hip

Case 1 H Y a woman 29 years old with progressive pain of the left hip since



Figure 13 Case 2 A osteoarthritis of the dysplastic hip with deformity of the femoral head and cyst in its lateral part B three years after the shelf operation combined with release of the muscles around the hip

she was the age of 24 There was no limitation of motion X ray showed marked acetabular dysplasia with formation of a cyst (Figure 12 A) but the cartilage space was well preserved. The shelf operation was performed with release of the muscles about the hip followed by skin traction of the affected leg for four weeks Six months after operation the hip was painless and six months later the limp also disappeared Roentgenograms made four years after operation showed that the shelf created at the proper site was organized well adapted to and supported the femoral head (Figure 12 B)

Case 2 F K., a boy 19 years old with severe pain in the right hip for six months He walked poorly with a stick. Examination revealed no limitation of hip motion Roentgenograms showed a marked acetabular dysplasia and a mushroom shaped deformity of the femoral head with a cyst in its outer non weight bearing portion However there was no narrowing of the cartilage space (Figure 13 A) The shelf operation was performed in combination with release of the muscles about the hip followed by skin traction of the involved leg for four weeks One year after operation the patient was completely free from pain and weakness of the hip also disappeared Roentgenograms made three years after operation revealed that the shelf was incorporated and well adapted to the femoral head. The cyst had almost completely disappeared (Figure 13 B)

2 Combination of shelf operation osteotomy and muscle release operation

(1) Combination of shelf operation varisation of the femoral neck and medial displacement of the shaft.

Case 3 N S a woman aged 50 years Progressive pain in the right hip had begun

two years previously Mobility of *right hip flexion to 90 degrees abduction to 10* degrees adduction to 90 degrees and rotation zero Roentgenograms showed a *markedly dysplastic acetabulum an outward migration of the femoral head* extensive cyst formation and a slight narrowing of the cartilage space (Figure 14) As may be seen in this figure several cysts are arranged in the oblique equatorial plane in the femoral head along which a shearing stress is thought to act The shelf operation was carried out in combination with varisation of the femoral neck and medial displacement of the shaft by osteotomy A long hip spica cast was applied and was worn for two months Six months after operation the patient was relieved from pain and moreover weakness of the hip had also disappeared There was no limitation of the hip motion As seen in the roentgenogram (Figure 14 B) made *seven years after operation the right hip was nicely reconstructed resulting in a* remarkable restoration of the degenerative changes in both the bone and the *articular cartilage Numerous thickened vertical longitudinal trabeculae formed in* the femoral head during these seven years This suggests that a load on the femoral head is vertically transmitted along the longitudinal trabeculae to the shaft This shows that the trabecular architecture in the femoral head had been reconstructed to adapt itself to the changes in mechanical condition caused by the operations mentioned above

In this case the restoration of the degenerative changes might have been obtained by varus osteotomy alone valgus osteotomy combined with release of the muscles alone or also by oblique displacement osteotomy alone

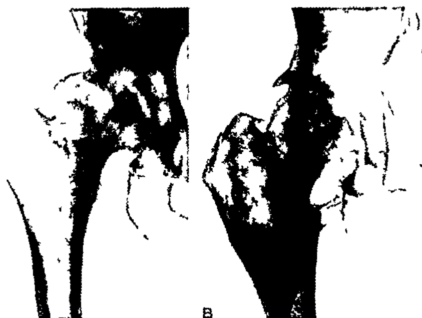


Figure 14 Case 3 A osteoarthritis of the dysplastic hip with several cysts arranged in the oblique equatorial plane of the femoral head B seven years after the reconstructive operation and medial displacement of the femoral shaft



Figure 15 Case 4 A an osteoarthritic hip with marked acetabular dysplasia and varus anteversion deformity of the femoral neck B five years after combined operations of shelf operation valgisation and derotation of the femoral neck medial displacement of the shaft and muscle release operation

(ii) Combination of the shelf operation valgisation of the femoral neck and medial displacement of the shaft by osteotomy and release of the muscles around the hip

Case 4 N I a woman 20 years old with dull pain in the left hip There was no limitation of the hip motion Roentgenograms revealed a marked dysplasia of the acetabular roof and an extreme varus anteversion deformity of the femoral neck. However no narrowing of the cartilage space was found (Figure 15) The shelf operation was carried out in combination with valgisation and derotation of the femoral neck and medial displacement of the shaft by intertrochanteric osteotomy Tenotomy of the adductor muscles was not performed because they were relaxed by medial displacement of the shaft However the abductor muscles were released because they were stretched by valgisation of the femoral neck. The limb was immobilized in a long hip spica cast for two months The patient was relieved from pain and weakness of the hip disappeared six months after operation Roentgenograms made five years after operation revealed that the affected hip was reconstructed into the mechanically stable condition (Figure 15) As seen in this figure the longitudinal trabeculae in the femoral head are thick compact and radiated proximately from the calcar femorale of the femoral neck in a fan like fashion If it is indeed true that form follows function this region morphologically suggests that a load placed superiorly on the femoral head is transmitted concentrically to the calcar femorale of the femoral neck This fact was also proved by a phot

study (Figure 16) Therefore the longitudinal trabeculae in the femoral head are completely released from the shearing stress

Case 5 C.T a woman 57 years old had had pain in the right hip for five years It became progressively worse in degree and duration Right hip motions were flexion to 60 degrees abduction to 15 degrees adduction to 15 degrees and rotation zero Roentgenography showed a marked acetabular dysplasia calcification of the joint capsule covering the lateral part of the femoral head narrow cartilage space and mushroom shaped deformity of the femoral head with a medial osteophyte and a large cyst in the lateral part (Figure 17) In this case combined operations composed of the shelf operation bone grafting in the cyst valgisation of the femoral neck and medial displacement of the shaft by intertrochanteric osteotomy and release of the abductor muscles were carried out A long hip spica cast was applied and was worn for two months She was relieved from pain four months after operation Weakness of the hip also disappeared five months later Roentgenograms made four years after operation showed a marked restoration of the degenerated areas (Figure 17 B As may be seen in this figure the shelf created united with the calcified joint capsule and adapted itself to the femoral head The cyst in the femoral head subsided and cartilage space increased in width

Case 6 M M a woman 51 years old has had increasing pain in the right hip for ten years She walked poorly with a stick. Right hip flexion to 85 degrees abduction to 10 degrees adduction to 20 degrees and rotation zero Roentgenography showed a mushroom shaped deformity of the femoral head with its outward migration from the center of the acetabulum accompanied by formation of a large medial osteophyte and a large cyst in the lateral non pressure portion of the head There was almost complete obliteration of the cartilage space (Figure 18 A) In this case

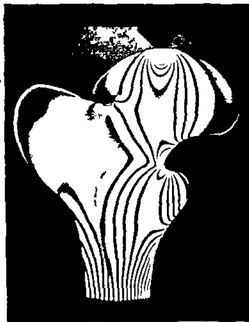


Figure 16 Case 4 Photoelastic study shows that a vertical load acting on the femoral head is transmitted concentrically to the cal ar femorale of the femoral neck



Figure 17 Case 5 A advanced osteoarthritic hip with acetabular dysplasia calcification of the joint capsule covering the lateral part of the femoral head mushroom shaped femoral head having a large cyst and medial osteophyte and narrowing of the cartilage space B four years after combined operations i e shelf operation bone grafting in the cyst valgisation of the femoral neck medial displacement of the shaft and release of the muscles

combined operations composed of the shelf operation bone grafting in the cyst, and valgisation of the femoral neck and medial displacement of the shaft by inter trochanteric osteotomy were carried out (Figures 18-B) Moreover the abductor muscles were released The limb was immobilized in a long hip spica cast for two months. The patient was relieved from pain six months after operation Stability of the hip was also gradually regained in the course of one year thereafter Roent genograms made five years after operation showed marked restoration of the degenerative changes (Figure 19) As may be seen in this figure the shelf created at the proper site was replaced with new bone and adapted itself to the femoral head and the cartilage space increased in width In the femoral head the cyst was repaired and the longitudinal trabeculae placed in the vertical position markedly increased in number and thickness while decalcification occurred in the medial osteophyte In this reconstructed joint it is suggested that a load on the femoral head is transmitted vertically along the longitudinal trabeculae to the shaft and in consequence the medial osteophyte is released from mechanical stress It is evident that the improvement of the mechanical condition in the joint combined with reduction of pressure caused by muscle tension resulted in reconstruction of the longitudinal trabeculae in the femoral head and decalcification of the medial osteophyte





Figure 18 Case 6 A osteoarthritic hip with an outward migration of the femoral head from the center of the acetabulum accompanied by formation of a large medial osteophyte and a large cyst in the lateral portion of the femoral head and almost complete obliteration of the articular space B diagram showing the combined procedures composed of the shelf operation bone grafting in the cyst valgisation of the femoral neck medial displacement of the femoral shaft and muscle release operation

DISCUSSION

In this paper the biomechanism responsible for development of osteoarthritis in the dysplastic hip was considered on the basis of the results from clinical and experimental studies and also the study of the architecture of the trabeculae in the upper end of the femur From the results obtained the basic principles were defined for operative treatment for various types of osteoarthritis of the dysplastic hip

It is supposed that in cases with acetabular dysplasia not only an excessive pressure on the small localized articular surfaces but also a shearing stress acting on the longitudinal trabeculae of the femoral head plays an important role in the development of degenerative changes in the joint Pathological changes which are thought to be caused by shearing stress on the longitudinal trabeculae are clearly seen in Cases 2 (Figure 13 A) 3 (Figure 14 A) 5 (Figure 17 A) and



Figure 19 Case 6 five years after operation

6 (Figure 18 A) In cases 2 5 and 6 the cyst is located in the lateral part of the femoral head which is subject to least pressure In Case 3 several cysts are arranged in the oblique equatorial plane along which a shearing stress is thought to act

In early cases with maked acetabular dysplasia it was shown that the shelf operation if it is performed with an exact technique and is combined with the muscle release procedure arrests progress of degenerative changes in the joint and promotes its regeneration In nine advanced cases the joint was reconstructed by a combination of the shelf operation valgisation with or without derotation of the femoral neck medial displacement of the shaft and the muscle release procedure In three other advanced cases the joint was reconstructed by a combination of the shelf operation varisation of the femoral neck medial displacement of the shaft and the muscle release procedure In all these cases the pathological changes were repaired and numerous thickened vertical longitudinal trabeculae were reconstructed

By means of the shelf operation the contact areas of the articular surfaces increase in size resulting in wide distribution of the load over the femoral head By valgisation of the femoral neck the longitudinal

trabeculae are released from shearing stress By varisation of the femoral neck the contact areas of the articular surfaces increase in size and the load on the femoral head is reduced due to relaxation of the muscles about the hip However the essential procedure for reconstruction of the dysplastic hip into the mechanically stable condition is the shelf operation combined with medial displacement of the shaft and release of the muscles about the hip by which the load on the femoral head is reduced distributed widely over the femoral head and transmitted vertically to the shaft Under this condition numerous thickened vertical longitudinal trabeculae are formed in the femoral head even though the femoral neck is placed in the varus position as shown in Case 3 (Figures 14 A and B)

The gains from cutting the bone angulation and displacing the shaft are well documented but the mechanism of pain and the reversal of the degenerative process is still obscure The procedures advocated by *McMurray Pauwels* and *Voss* are in fact variations of one procedure which must be modified according to the clinical and roentgenological findings It is a mistake to use a stereotype technique for all patients It is not realistic to expect one operation to be best for all of them Though the greatest usefulness of the *Voss* temporary hanging hip procedure is for a patient too old to withstand major surgery or with advanced arthritis of the hip and a range of hip motion too small to justify other procedures this procedure is used also in combination with the shelf operation and valgisation of the femoral neck as shown in the cases presented here Though *Pauwels* varus osteotomy gives an excellent result in patients with acetabular dysplasia accompanied by coxa valg luxans the shelf operation combined with the muscle release procedure is also useful in patients with acetabular dysplasia too excessive to justify varus osteotomy

The results obtained in our studies revealed that the shelf operation combined with the muscle release procedure is applicable to the early case with marked acetabular dysplasia and that the shelf operation combined with medial displacement of the shaft and muscle release procedure is applicable to advanced case Furthermore in these latter cases varisation or valgisation of the femoral neck can be additionally done according to the clinical and roentgenological findings

SUMMARY

1 The principles of treatment for osteoarthritis of the hip with incongruity were described On the basis of the principles the affected

hip was reconstructed into the mechanically stable condition by various combinations of the shelf operation varisation or valgisation of the femoral neck medial displacement of the shaft and muscle release operation in 50 cases In all cases good results were obtained

2 In 38 early cases with a marked acetabular dysplasia the shelf operation was performed in combination with release of the muscles about the hip

3 In 12 advanced cases with a marked acetabular dysplasia and deformities of the femoral head and neck the affected hip was reconstructed into the mechanically stable condition by combination of the shelf operation intertrochanteric osteotomy and release of the muscles about the hip through which a load on the femoral head is reduced distributed widely over the femoral head and transmitted vertically to the shaft

RÉSUMÉ

1 Il est donne la description des principes du traitement de l ostéo arthrite de la hanche Sur la base de ces principes la hanche a été reconstruite dans 50 cas de manière a obtenir une condition mécanique stable par differentes opérations combinées butée complétant le toit du cotyle varisation ou valgisation du col fémoral déplacement médial du corps femoral et relachement des muscles De bons résultats ont été obtenue dans tous les cas

2 Dans 38 cas precoces avec dysplasie marquée du cotyle l opération de butee du toit a ete pratiquee en combinaison avec le relachement des muscles autour de la hanche

3 Dans 12 cas avancés avec dysplasie marquée du cotyle et déformite de la tête et du col du femur la hanche atteinte a été reconstruite de manière a obtenir une condition mécanique stable par une opération combinee de butee du toit du cotyle d osteotomie intertrochantérienne et de relachement des muscles autour de la hanche grâce à laquelle la charge sur la tête femorale est réduite du fait qu elle est plus largement repartie et transmise verticalement au corps du fémur

ZUSAMMENFASSUNG

1 Die Prinzipien der Behandlung der osteoarthritischen inkongruenten Hufte werden beschrieben Auf Grundlage dieser Prinzipien wurde die erkrankte Hufte mittels veschiedener Kombinationen von Pfannendachoperationen Varus und Valguseinstellung des Schenkelhalses medialer Schaftverschiebung und Muskelauslösungsoperationen in 50 Fal

len in eine mechanisch stabile Verfassung gebracht In allen Fällen wurden gute Resultate erzielt

2 In 38 frühzeitigen Fällen mit ausgesprochener Acetabulardysplasie wurde *die Pfannendachplastik im Kombination mit der Auflösung* der Muskeln der Hüftregion ausgeführt

3 In 12 vorbeschrittenen Fällen mit ausgesprochener Acetabulardysplasie und Deformiteten des Femurkopfes und Halses wurde in der erkrankten Hüfte mittels Pfannendachplastik intertrochanterer Osteotomie Muskelauslösung der Hüftregion ein mechanisch stabiler Zustand wiederhergestellt durch den die Belastung des Femurkopfes verringert weit über den Femurkopf verteilt und vertikal auf den Schaft überführt wird

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INTERTROCHANTERIC VALGUS OSTEOTOMIES IN HIP ARTHROSIS

By

Bengt Tillberg

Received 23 vi 67

Surgery in hip arthrosis is a problem with many facets and a problem which is very far from being solved At the Orthopaedic Clinic in Härnosand arthrodesis is considered to be a method which gives good results (11) but it is in many hands an operation with infrequent bone union Furthermore this arthrodesis has limited indications (11 13) and thus there remain many patients with coxarthrosis who must be treated in other ways A simple method which has attracted much interest is the intertrochanteric valgus osteotomy which was introduced by *Lorentz* (12) and developed by *McMurray* (14) This technique used to be complicated by the long period of after care owing to the plaster fixation and the consequent increased rigidity of the patient In the last decade conditions have improved owing to the use of internal fixation (2 8 10 21) and the method has regained its popularity A number of follow up surveys have also been published but the majority of these show a miscellaneous range of etiologies and only a small number are comprised solely of coxarthroses cases (7) To confuse the issue further some of the reported cases had been treated by conventional plaster fixation (3 13 14 16 22) some by both internal fixation and plaster (18) and yet others by a mixture of either internal fixation or plaster (1 15 20) Therefore the author thought it important to publish the results of a series of operations performed on clear coxarthroses in which internal fixation without plaster was used followed by uniform after care of the patient

In the published surveys there is a large divergence in the methods of reporting results which makes comparisons difficult *Gade* (6) introduced a standard assessment procedure which has been developed

and used by *Shephard* (19 20). A more recent follow up survey of conservatively treated hip arthroses has employed the same assessment index (5).

MATERIAL

This series is based on patients with primary idiopathic arthrosis or secondary arthrosis owing to epiphyseolysis for which it was not possible to make a differential diagnosis. In the period 1955–60 operations were performed on 115 patients in the age range 3[illegible] to 71 years (average 56 years). A total of 124 valgus osteotomies were performed with the same technique as 9 patients were operated on bilaterally. Different operative techniques have been employed in the treatment of the contralateral joints of 10 patients as can be seen in Table 1. The sex distribution is fairly even with 63 male and 61 female hips and 70 of the patients had bilateral arthrosis. Before the operation the patients had pain for an average period of more than 4 years. 8 patients died, one of these post operatively owing to a cerebral embolism while 7 died several years later from causes not connected with the operation. All the remaining patients were examined by the author after a minimum post-operative period of 5 years (average period 6.5 years). The results are reported both according to subjective, objective and radiological assessment and also employing the index of *Gade* (6).

Table 1

		Male	Female	Numbers
Unilateral osteo arthritis with osteotomy		27	27	54
Bilateral osteo arthritis	Unilateral osteotomy	30	21	51
	Bilateral osteotomy	4	5	9
	Other side other operation	2	8	10
Sum		63	61	124

Arthrodesis 1 Smith Petersen 4 Girdlestone 2 Moore 3

INDICATIONS AND OPERATIVE PROCEDURE

The main indications were aching at rest and pain on weight bearing. In addition relatively good mobility was required, i.e. flexion capacity of at least 60 degrees (13) and an adduction capacity corresponding to the intended valgus position (16 23). After the introduction of varus osteotomies X-rays are taken to an ever increasing extent both in abduction and adduction (17) in order that operative procedure could be modified to produce the best congruence between caput and acetabulum.

Via an incision 5 inches long and an approach through the posterior portion of vastus lateralis the shaft of the femur and the intertrochan

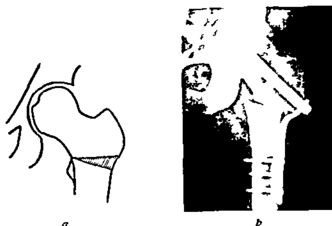


Figure 1 a and b Diagram of operative procedure and radiological appearance of the completed valgus osteotomy



Figure 2 Radiological appearance of the arthrosis hip a) pre-operatively b) 8 months post operatively and c) 7 years post operatively

teric line were exposed Very often a wedge was excised as shown in Figure 1 a (2) with a lateral base in accordance with the planned valgus position The wedge was also designed to afford correction of the flexion contracture Afterwards the rotation malposition was corrected and the medial displacement of the distal fragment was performed In the present series this medial displacement extended to the width of the cortex in 25 cases up to half the diameter of the femur in 67 operations and more than half the diameter of the femur in the remaining cases

Before internal fixation was introduced plaster fixation was used in the mid fifties the Kessel plate (9) was employed in a few cases (Table 2) but late in 1955 the method of *McKee Nissen* (10 21) was adopted—*i e* fixation with plate and nail cf Figure 1 b Despite the rigid fixation which prevents the maintainance of compression between caput fragment and shaft following resorption (23) the method has been proved neither to be a disadvantage nor to endanger healing This is perhaps due to the fact that the nail is given an extra blow before the nut is tightened so substantial compression is obtained in this way in valgus osteotomies

Postoperative care regularly consisted of 6 weeks bed rest and physiotherapeutic treatment of the knee was instituted 3 weeks postoperatively After 6 weeks the patients were allowed up on crutches and systematic walking exercises were begun and training for the activities of daily living After a total of a couple of months in hospital the patients were allowed to go home with continued exercise schedules but out patient physiotherapy was continued only in a few cases

Complications There were 8 cases of postoperative hematoma with delayed healing infection superficially at the site of operation in 2 cases and thrombosis in 10 cases Bronchial pneumonia occurred in 3 cases and there was also a fatality owing to cerebral hemorrhage

RESULTS

Initially plaster fixation was used and afterwards for a short period the Kessel plate before the nail and plate procedure of McKee Nissen was adopted During the period 1955–60 which this survey covers 6 patients were treated by plaster fixation alone 13 operations were performed with the Kessel plate but in the majority of these cases the valgus position sought could not be maintained and in 8 of the cases with the *Kessel* plate instability compelled us to apply plaster in ad

Table 2

Fixation	Numbers	Pseudo arthrosis	Ankylosis	Failures
Plaster only	6	1	2	4
Kessel plate { Only	5	2	0	2
Kessel plate { + plaster	8	4	1	5
Nail plate a m. McKee Nissen	97	6	0	1[illegible]

dition (Table 2) 5 of these cases with plaster fixation suffered thrombosis postoperatively and 11 of the above 19 cases were not successful as their discomfort was not alleviated 7 developed into pseudoarthroses and 3 cases healed primarily as arthrodesis i e considered unsuccessful as osteotomies Therefore as 58 per cent of these 19 cases were not successful the need for better internal fixation by nail and plate was obvious In order to obtain a series consisting solely of coxarthroses operated upon in a uniform way and with fixation by nail and plate ad modum McKee Nissen the above 19 cases have been excluded from the following account

Therefore in 97 hip operations of valgus type utilizing McKee Nissen fixation 70 per cent of the patients consider that the operation was worth performing 18 per cent were satisfied but had reservations as they thought that their mobility had become worse or that they had become weaker in the leg after the operation 12 per cent dissatisfied with the result of the operation 3 because other troubles had arisen in the back and knee and 9 cases because their troubles were just as pronounced as before the operation 16 per cent were completely pain free while a further 42 per cent had insignificant discomfort not affecting their activity but noticeable after extreme weight bearing or change of weather Weight bearing pain alone occurred in 9 per cent and aching only at rest in 3 per cent but in all cases the pain was considerably less than before the operation 30 per cent continued to have both weight bearing pain and aching at rest but 18 per cent of these were considerably better than they were before the operation No change had occurred in 12 per cent of the cases where the operation must therefore be regarded as unsuccessful Thus 88 per cent of the patients felt some improvement after operation as is shown in summarized form in Table 3 where the results are reported according to the Gade index

Table 3 Pain (in groups according to Gade)

	%
Excellent	55
Good	23
Fair	10
Poor	12

7 of the 12 unsuccessful cases (12 per cent) were reoperated on by another method 4 cases of arthrodesis 2 endoprostheses ad modum Moore and 1 case of arthroplasty ad modum Smith Petersen At the follow up these patients could not be recorded as osteotomies and

therefore the clinical as well as the radiological findings presented here will cover only 90 hip operations

In general the patients themselves were allowed to decide when they could dispense with the aid of sticks after the operation 12 patients stopped using sticks within 6 months 24 patients used sticks for between 6 and 12 months and 14 patients stopped using sticks after a period of more than 1 year In all, 56 per cent did not use sticks at the time of last examination 25 of the remaining 44 per cent who continue to use sticks had bilateral arthrosis and 10 of them had been operated on bilaterally Trendelenburg s tests were negative in 53 per cent doubtful in 30 per cent and clearly positive in 17 per cent 98 per cent could unaided and 98 per cent could cope with personal hygiene and shoes unaided and 98 per cent could cope with personal hygiene

Table 4 Ability to work

	%
None	43
Clerical work	5
Homework	34
Industrial work	11
Heavy work	7

Table 5 Restriction of functional activity

	%
Mild	41
Moderate	46
Severe	13

Many of the patients who had previously done heavy work in agriculture forestry or industry could not perform similar work in spite of the operation At the time of follow up 57 per cent had wage earning work and of these 5 per cent did their work while sitting 34 per cent had lighter work mainly as housewives, while 11 per cent still had fairly heavy industrial work and 7 per cent heavy agricultural and forestry work (Table 4) Of the remaining 43 per cent who did not work 9 per cent were too old to work and 34 per cent were retired with an early pension owing to the hip trouble Summarizing Table 5 shows restriction of function according to the Gade index i e the ability to cope with the activity of daily living including Trendelenburg the use of sticks and the capacity to work

Initially the indications were not completely clear but developed as

our experience of the operation increased thus a number of patients which did not fulfill the previously stated conditions were operated on It was found at the follow up that of the 12 unsuccessful operations 7 cases had adduction contractures before the operation 5 had no adduction ability and 5 had flexion of less than 60 degrees Clinical examination showed that 60 cases had flexion contractures before the operation and that 80 per cent of these had been corrected 35 out of 45 outward rotation malpositions were corrected while 14 new ones developed post operatively so that in all outward rotation contractures were present in 27 per cent following the operation The changes which took place with respect to mobility are shown in Table 6 These changes were generally slight and the mean value of the Gade index rose from 45 before the operation to 50 at the time of follow up This increase is not statistically significant and therefore one cannot expect to be able to increase the mobility appreciably by this operation It is very important to be aware of this when a patient is informed pre operatively of the result which can be justifiably expected from the operation This was also shown at the follow up when 12 patients declared themselves to be less pleased with the operation because their mobility had become worse than they expected The range of motion before and after the operation is summarized in Table 7 in terms of the Gade index

Table 6 Changes in mobility by the operation in per cent

After operation	Increased	Unchanged	Decreased
Flexion	30	36	34
External rotation	23	52	25
Abduction	51	39	10
Adduction	38	47	15

Table 7 Range of motion (according to Gade)

Mobility before operation	Mobility after operation				
	Excellent	*Good*	*Fair*	*Poor*	Sum in %
Excellent	31	5	0	0	37
Good	22	17	8	2	57
Fair	0	2	0	1	4
Poor	0	1	0	1	2
Sum in %	59	28	9	4	100

Table 8 Radiographic changes in per cent

	Better	Unchanged	Worse
Joint space	56	29	15
Cysts	50	28	22
Sclerosis	23	57	20
Osteophytes	0	51	49

X rays conventionally analysed showed improvement in the joint space in 56 per cent of the cases (Table 8) (1 18 20) There were healed cysts in 50 per cent and diminished sclerosis in 23 per cent It was shown radiologically that the arthrosis process which is usually seen to progress in untreated hips ceased after the operation and sometimes healed to a large extent (see Figures 2 a–c)

The nail plate and screws were of stainless steel but owing to the discomfort caused by electrolytic action (4) we were compelled to extract these implants in 43 per cent of the cases Of the remaining 57 per cent who retained their osteosynthesis material about half had tenderness at the site of operation As this also was probably caused by electrolytic action around plate and nail consideration was given to changing to vitallium implants Unfortunately plates of this material cannot readily be bent and this is just what one is sometimes compelled to do in order to adapt the valgus angle to the adduction ability and anatomical conditions of each patient and also to make possible the medial displacement of the distal fragment

SUMMARY

Valgus intertrochanteric osteotomies were performed on 97 patients with hip joint arthrosis and fixation was achieved by plate and nail according to McKee Nissen These operations were carried out in the Orthopaedic Clinic in Härnösand in the period 1955–60 and the follow up was undertaken on average 6 5 years postoperatively

Improvement as regards aching at rest and weight bearing pain was present in 88 per cent of the cases 57 per cent had resumed work of some form and 87 per cent demonstrated the ability to cope with daily living On the other hand mobility was scarcely affected by the operation As determined radiologically the arthrosis process was found to have ceased and there were increased joint spaces and healed cysts in half of the cases

RESUME

Des osteotomies intertrochanteriennes valgues ont ete pratiquees chez 97 malades souffrant d arthrose de la hanche

La fixation a ete accomplie au moyen de plaques et de clous d apres la methode McKee Nissen

Ces operations ont été effectuees a la Clinique Orthopedique de Här nösand dans la periode 1955–60 et les examens complementaires ont ete entrepris en moyenne 6 ans et demi apres l operation

On a constate une amelioration en ce qui concerne les douleurs tant au repos que provoquees par le port d un poids dans 88 pour cent des cas 57 pour cent avaient une certaine forme de travail 87 pour cent ont montre qu ils étaient capables de vivre a peu pres normalement La mobilité avait d ailleurs a peine ete affectee par l operation Comme déterminé par la radiographie on a trouve que le processus de l ar throse s etait arreté et qu il y avait des espaces interarticulaires plus larges et des cystes guéris dans la majorite des cas

ZUSAMMENFASSUNG

Intertrochanterische Valgusosteotomien wurden an 97 Patienten aus gefuhrt deren Huftgelenk mittels Platte und Nagel gemäss McKee Nissen fixiert worden war Diese Operationen wurden an der ortho-padischen Klinik in Harnosand wahrend des Zeitraumes 1955–60 aus gefuhrt und die Nachuntersuchung wurde durchschnittlich 6 5 Jahre der Operation vorgenommen

Besserung hinsichtlich Ruheschmerz und Belastungsschmerz war in 88 Prozent der Falle vorhanden 57 Prozent hatten Arbeit in irgend welcher Form wieder aufgenommen und 87 Prozent zeigten die Fahig keit das tagliche Leben zu bewaltigen Andrerseits war die Beweglich keit kaum beeinflusst durch die Operation Rontgenologisch wurde ge funden dass der arthrotische Prozess aufgehört hatte und dass erweiter ter Gelenksraum und geheilte Cysten in der Halfte der Falle gesehen werden konnte

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CASE OF CHONDROSARCOMA WITH PULMONARY AND SKELETAL METASTASES AFTER HEMIPELVECTOMY, SUCCESSFULLY TREATED WITH ^{35}S SULFATE

By

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INTRODUCTION

In a recent paper in this journal (*Boström et al* 1968) the need for new methods of treatment of chondrosarcoma was discussed On the basis of present knowledge of the biochemistry of these tumors the following two biochemical principles for the retardation of tumor growth were suggested 1 Retardation of tumor growth by interference with the formation of its matrix e g by drug inhibition of the biosynthesis of sulfated glycosaminoglycans (*Boström et al* 1964) or by enhancing the breakdown of preformed cartilaginous matrix (*Thomas* 1956) 2 Introduction of a precursor which when built into the sulfated glycosaminoglycans will cause damage to the malignant cells Both principles are related to the fact that sulfated glycosaminoglycans are important constituents of the matrices of such tumors and moreover that there is indication that the tumors have an increased formation rate of these compounds

The approach of *Gottschalk et al* (1959 a b) *Andrews et al* (1960)

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A preliminary account of this work was given at the Annual Meeting of the Swedish Orthopedic Association Dec 1–4 1966 Stockholm Sweden

and *Bolstein & Marcus* (1963) who administered large doses of ^{35}S sulfate to patients with advanced chondrosarcoma exemplifies the utilization of the second of the two principles. The radioisotope was given in amounts of 0.6–1.2 C. With this dosage temporary arrest of growth and relief of pain were noted in several instances but in no case was a cure of the patient obtained. It was also established that the limiting factor in the therapeutic use of ^{35}S sulfate is the radio-sensitivity of the hematopoietic system. Marked depression of bone marrow activity invariably followed the administration of the large doses of ^{35}S employed. However, the marrow function was completely restored in about one month. Consequently, the possibility of multiple courses of ^{35}S treatment for patients who respond well was suggested by *Bolstein & Marcus* (1963).

The purpose of the present paper is to report the effects of treatment with ^{35}S sulfate in an operated case of chondrosarcoma in which the principle of multiple courses referred to above was applied. In order to increase the ratio of exposure between tumor and bone marrow, arterial injection of the isotope was used on some occasions. In this way it was possible to administer a total dose of radioactivity *higher than any reported earlier, without protracted damage to the* bone marrow. The result of the treatment was also more favorable. An apparent devitalization of a skeletal metastasis was obtained. There was also arrest of growth of pulmonary metastases.

CASE REPORT

Patient, male, aged 74, previously healthy with no family history of malignancy. In 1959 he complained of pain in the left gluteal region. Roentgenological examination early in 1960 revealed skeletal destruction in the tuberosity of the left ischium; the diagnosis of chondrosarcoma was verified histologically from biopsy material. In February 1960 a resection of the left ischium was performed at the Department of Orthopedic Surgery, Norrbacka Institutet, and the tumor was regarded as radically removed. At the end of 1963, however, local recurrence of the tumor was observed, and during the following year there was a slow growth of the tumor into the left proximal femoral region.

The patient was admitted to the Department of Surgery at the Serafimer hospital in September 1964. During the next six months he was treated with cytostatics (methotrexate) through an indwelling catheter in the left iliac artery. This treatment was ineffective. Tumor growth continued and the patient was readmitted to the Orthopedic clinic in March 1965. — At that time the tumor occupied part of the pelvis and impaired the bladder function. Since no metastases could be detected in the lungs or elsewhere, a left hemipelvectomy was performed as a palliative and



Figure 1 Roentgenologic survey of lungs before (A) and 2 years after (B) introduction of 35S sulfate treatment Widespread metastases were observed on both occasions but there is no evidence of progress in the disease

hopefully curative measure in April 1965 The operation was considered radical as judged by macroscopic and microscopic examination of the tissues removed The postoperative course was uncomplicated and training with a prosthesis was started

In November 1965 pulmonary roentgenograms showed (Figure 1 A) the presence of a large number of small areas of increased density bilaterally which were considered to be chondrosarcoma metastases Attempts to obtain needle biopsies for histologic confirmation of this diagnosis were unsuccessful

Soon thereafter treatment with high doses of radioactive sulfate was started at the metabolic ward of the Medical clinic at the Serafimer hospital The total amount of radioactivity given was 1 735 C, in seven separate doses some of which were given intravenously and others intra arterially as shown in Table 1

After the first four injections the patient started to feel pain in the distal part of the right tibia. A roentgenogram of this region showed destruction of the bone and the presence of a bone metastasis was suspected (Figure 2 A) Surgical exploration in January 1966 revealed a subcutaneous bluish gelatine like lobated tumor destroying the cortical la er of the tibia and growing into the marrow cavity Macroscopically the tumor had the appearance of a chondrosarcoma the diagnosis was confirmed b microscopic examination In order to achieve the highest possible concentration of radioactive ulfate in the tibial tumor the next dose was gi en intra arteriall into the right popliteal artery After two additional intra en us doses of radioactivity the isotope treatment was concluded in Jul 1966

During the spring of 1966 the pains in the right tibia disappeared slowly and the patient as again able t stand on his leg and to resume training with the prosthe i At the end of November i e about 10 months after the bone biopsy roentgen grams of the chondrosarcomatous region in the tibia showed no increase in the iz f the tumor On the contrary a marked demarcation and sclerosis of

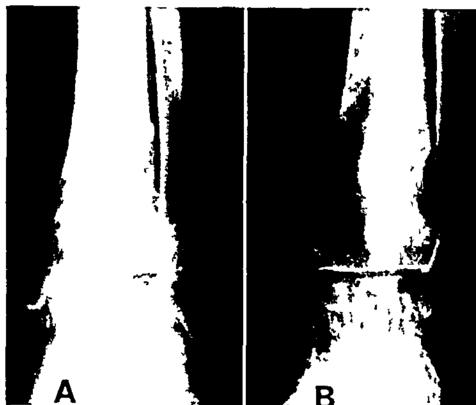


Figure 2 Tibial metastases of chondrosarcoma in January 1966 (A) and 10 months after introduction of ³⁵S sulfate therapy (B) On the former occasion diffuse bone destruction and cortical fragmentation were observed whereas after treatment there was marked sclerosis with a sharp border between the lesion and the surrounding bone and soft tissue

the metastasis was observed (Figure 2 B) A second surgical exploration of this region was made in November 1966 No extraskeletal tumor tissues were then seen macroscopically A dense fibrotic scar tissue was found in the muscles and the cortical layer of the tibia was hard and sclerotic No tumor tissue was observed in the cortical or cancellous bone The absence of viable tumor cells in the extensive biopsy material, was confirmed by a detailed microscopic investigation The last available roentgenogram of the tibia taken in October 1967 showed no signs of recurrence of the malignant process With regard to the pulmonary metastases frequent roentgenologic surveys of the lungs from the beginning of the isotopic treatment in November 1965 until October 1967 have failed to show any definite increase in size of the metastases or any other sign of progress in the pulmonary involvment (Figure 1 B)

The patient s general condition which was reasonably good throughout the isotopic treatment has steadily improved during the two last years Since his discharge from the metabolic ward in March 1966 he has been leading an essentially

Table 1

Injection no	Date	Dose mC	Administered into	Urine collection days
I	29 Nov 1965	250	Superior vena cava	7
II	6 Dec 1965	750	Right bronchial artery	14
III	20 Dec 1965	250	Right bronchial artery	7
IV	27 Dec 1965	250	Cephalic vein	14
V	17 Feb 1966	250	Right popliteal artery	–
VI	17 May 1966	235	Cephalic vein	–
VII	18 July 1966	250	Cephalic vein	–

Date dose and route of administration of the seven injections of ^{35}S sulfate Duration of urine collection for radio assay is also given – indicates that urine was collected for safe disposal only

normal but sedentary life in his home except for four short periods in the hospital for treatment or checkups However the patient recently (Oct. 1967) developed a diabetes mellitus which is well controlled with a small dose of tolbutamide

EXPERIMENTAL

Isotope Treatment

The isotope used in the treatment was obtained as a carrierfree neutral sterile solution of sodium sulfate ^{35}S from the Radiochemical Centre Amersham England After carefully controlling the radio activity of each batch of the isotope the actual dose for administration was diluted to 10 ml with sterile normal saline [1] The isotope was injected over a period of about five minutes through an indwelling catheter Table 1 shows the amount of ^{35}S-sulfate given each time the administration routes and the injection days

Strict precautions were taken in order to reduce the hazards of undue isotopic contamination Routines normally employed in cases of highly infectious diseases were used in the general management of the patient during the first two months of intensive treatment and subsequently for at least 10 days after each single dose of ^{35}S sulfate Moreover during the first week after the injection the urine was quantitatively collected by means of an indwelling urethral catheter The

[1] Mr L. Johansson M A Radiophysical Institute Karolinska Institutet performed the radioactivity controls and the preparation of the different doses to be injected.

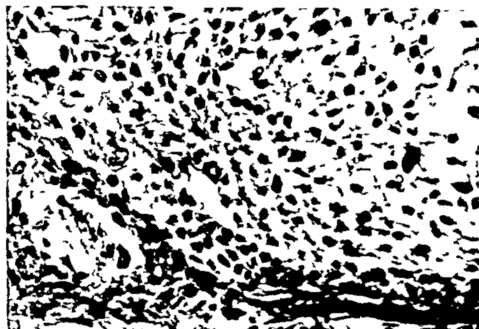


Figure 3 Microscopical section from biopsy of tibial metastasis (cf Figure 2 A) obtained in January 1966 Low-differentiated chondrosarcoma with typical structure containing immature chondroblastic tumor cells (× 400)

catheter was connected to plastic tubing draining into a plastic bottle which was kept in ice in order to prevent bacterial growth and subsequent derangement of sulfate conjugates The bottles were changed at scheduled times sealed in the patient s room and transported to a laboratory where facilities for the handling assay and disposal of high doses of radioactivity were available

Histologic Studies

Material for histologic examination of the chondrosarcomatous lesion was obtained on several occasions The primary tumor in the tuberosity of the ischium had the appearance of a typical chondrosarcoma The recurrent pelvic tumor had a very similar appearance with only very slight regressive changes in spite of the preceding treatment with cytostatics

The characteristic chondrosarcomatous appearance of the tibial metastasis before treatment with ^{35}S is shown in Figure 3 A section of the same metastasis ten months later was strikingly different (Figure 4) There was marked sclerosis and hyalinization of the tissue The



Figure 4 Section of the same metastasis 10 months after instituting ³⁵S sulfate treatment (cf Figure 2 B) Marked hyalinization and sclerosis of the tumor tissue containing but few tumor cells without signs of viability (× 400)

tumor seemed to be completely devitalized and there were no signs of viability among the few remnant tumor cells

Hematologic Studies

An estimate of the radiation received by the tumor tissue as compared with that received by the bone marrow could not be worked out Therefore frequent hematologic studies were made during the entire course of treatment to guide the timing of the isotope administration

Studies on the peripheral blood included determination of the number of erythrocytes leukocytes and thrombocytes as well as hemoglobulin concentration The results are summarized in Figure 5 In general as illustrated by this figure the hematologic complications were not very serious On two occasions during the treatment about one month and six months after its inception the hemoglobin level dropped to values around 9 g/100 ml The erythrocyte and thrombocyte counts remained at safe levels with the lowest values one month and four months after initiation of ³⁵S therapy The leukocyte count

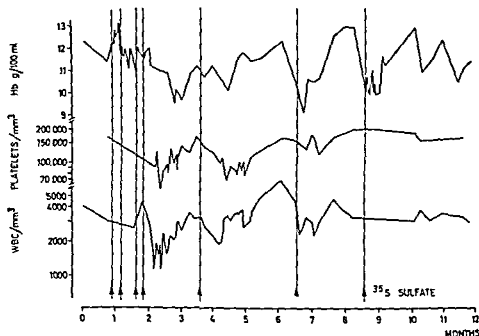


Figure 5 Level of hemoglobin platelets and white blood cells during treatment of the patient The arrows indicate the times when the isotope was injected

was somewhat more strongly influenced by the ^{35}S treatment It fell to 1 200 cells/mm³ after six weeks of treatment at which time one curie of radioactivity had been given Subsequent single doses of the isotope caused only minor reductions in the white cell count

Frequent samples of bone marrow were taken by sternal puncture during the course of treatment particularly during the first two months when marrow smears were investigated several times weekly No significant pathological changes were ever noted with respect to erythropoesis thrombocytopoesis or the appearance of reticular cells Between the tenth and fortieth day after the beginning of treatment myelopoesis was found to be hypoplastic with the occurrence of various numbers of damaged cells This was interpreted as indicating a mild to moderate toxic effect on myelopoesis Two months after the beginning of the treatment the bone marrow had normalized Subsequently no significant pathological changes in the bone marrow were observed At the last examination (Oct 1967) all the above mentioned hematologic parameters were normal

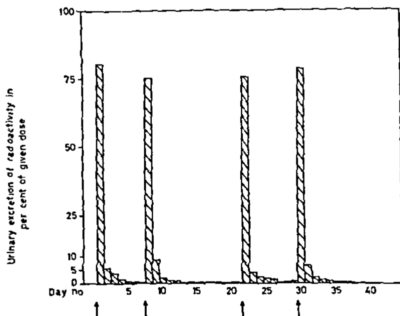


Figure 6 Schematic representation of daily urinary excretion of radioactivity following injections I–IV expressed as per cent of given dose The arrows indicate the times of isotope injection

Urinary Radio-Assays

The excretion of the radioisotope into the urine was examined after injections I–IV The radio assays included determination of total radioactivity and of ester sulfate radioactivity the ^{35}S activity in the inorganic sulfate fraction was calculated as the difference between total and ester sulfate activity No attempt was made to examine the occurrence of ^{35}S as neutral sulfur since previous studies have shown the excretion in this fraction to be negligible (see page 12) Total ^{35}S activity was measured at infinite thinness with a Geiger Müller counter equipped with a thin endwindow tube Aliquots of 100 µl of properly diluted (up to 10 000 times) samples of urine were applied to frosted aluminum plates and dried at 80–90 C As a reference 100 µl aliquots of a dilution of the isotope solution given to the patient were always used

The following method was applied for determination of ester sulfate ^{35}S The ester sulfate fraction was separated from inorganic sulfate by precipitation of the latter as $BaSO_4$ After centrifugation the supernatant was filtered through Munktell filter paper no OOH The excess

Table 2

Collection period	*Fraction*	*Injection no* I	II	III	IV
Whole period	Inorganic sulfate	79.2	71.2	67.1	81.6
	Ester sulfate	13.2	18.6	19.5	10.3
	Total	92.4	89.8	86.6	91.9
First 24 hours	Inorganic sulfate	69.6	58.9	57.7	70.0
	Ester sulfate	10.7	16.0	17.8	8.5
	Total	80.3	74.9	75.5	78.5
Second 24 hours	Inorganic sulfate	4.6	7.3	3.2	5.8
	Ester sulfate	0.8	1.4	0.7	0.7
	Total	5.4	8.7	3.9	6.5
Third 24 hours	Inorganic sulfate	2.8	1.5	2.1	2.2
	Ester sulfate	0.9	0.4	0.4	0.2
	Total	3.7	1.9	2.5	2.4

Urinary recovery of ^{35}S activity in per cent of administered dose after the first four injections

of barium ions was precipitated as $BaCO_3$ by bubbling CO_2 through the solution. Centrifugation and filtration rendered a clear solution, aliquots of which were plated for radio assay as described above.

As shown in Figure 6 and Table 2, approximately 90 per cent of the administered radioactivity was recovered in the patient's urine. Most of

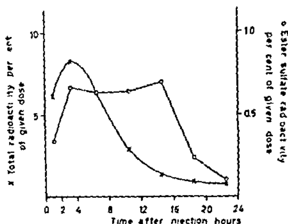


Figure 7. Excretion rate of total and of ester sulfate radioactivity during the first 24 hours after injection I. The excretion rates are expressed in per cent of the given dose excreted per hour.

this radioactivity was recovered during the first 24 hours and occurred in the inorganic sulfate fraction However as shown in Table 2 10 to 20 per cent of the dose was excreted in the form of ester sulfates This fraction was somewhat higher after doses II and III injected into the bronchial artery than after doses I and IV which were administered intravenously An analysis of urinary radioactivity on an hourly basis was performed during the first 24 hours of collection following injection I The excretion of total radioactivity mainly representing inorganic sulfate was highest during the first few hours with a peak at about 4 hours after injection (Figure 7) Radioactivity in the ester sulfate fraction on the other hand showed a more delayed excretion pattern presumably reflecting the appearance in the urine of different ester sulfates formed and excreted at different rates

DISCUSSION

The diagnosis of pelvic chondrosarcoma in the present case is well founded It is based on the typical symptoms the course of the disease and the characteristic roentgenographic and morphologic findings The same applies to the tibial metastasis the nature of which was also confirmed by microscopy With regard to the pulmonary lesions microscopical characterization of the suggested chondrosarcomatous structure is still lacking due to the obvious difficulty in obtaining representative biopsy material

The clinical course was strikingly changed in a favorable direction after initiation of ^{35}S therapy The patient s general condition improved considerably The tibial metastasis apparently was completely devitalized there was no further progress of the pulmonary involvement and there have been no signs of the appearance of new metastases To our knowledge such a therapeutic effect has not been demonstrated previously with ^{35}S treatment or cytostatic drugs The question then arises to what extent the advantageous course of the disease during the last two years can be credited to the ^{35}S therapy

It must be pointed out that some types of chondrosarcomas grow very slowly and that generalized metastases usually appear late in the course of the disease Neither can the possibility of a spontaneous regression of the metastases during the period of observation be completely excluded However in view of the recurrence and rapid growth of the primary tumor the failure of cytostatic treatment and the rapid

appearance of pulmonary metastases after hemipelvectomy it seems unlikely that the change in course was spontaneous We assume therefore that the cessation of growth of the pulmonary metastases and the devitalization of the tibial metastasis was in fact a result of the ^{35}S treatment The more favorable effect of this therapy than in previously reported cases may in part be due to a greater radiosensitivity of the tumor or to an earlier institution of treatment However in our opinion the most important factor was probably that the patient received the highest total dose of ^{35}S sulfate thus far reported in the literature

In spite of the higher dose of ^{35}S sulfate in the present case the bone marrow was only slightly affected in comparison to previous cases (*Gottschalk et al* 1959a and b *Andrews et al* 1960 *Botstein & Marcus* 1963) Nor were there any signs of damage to other tissues or any symptoms of a generalized radiation sickness On the contrary the patient s general condition has been good ever since the treatment was completed Whether his recently discovered diabetes has been precipitated by radiation injury of the beta cells of the pancreas or is only coincidental can not be established However it seems unlikely that such a radiation injury would not become manifest until two years after the institution of ^{35}S therapy Nevertheless animal experiments have shown that ^{35}S sulfate is taken up by the pancreatic islets This uptake occurs mainly in the vascular connective tissue strands and only to a limited extent in the specific cells (*Odeblad & Boström* 1952 *Norhagen & Odeblad* 1955 *Diderholm & Hellman* 1957)

The urinary radio assays performed in the present case gave results that are in agreement with those of previous studies in animals (*Laidlaw & Young* 1948 *Dziewiatkowski* 1949a and b *Boström et al* 1963) and in human (*Gottschalk et al* 1959a and b *Andrews et al* 1960 *Botstein & Marcus* 1963) the bulk of an administered dose of ^{35}S sulfate is swiftly excreted into the urine mainly as inorganic sulfate but to some extent also as ester sulfate It should be of interest in further therapeutic trials with ^{35}S sulfate to subject the urinary excretion of ^{35}S labeled ester sulfates to a closer analysis e g in order to elucidate the possible relationship between the mode of administration of the isotope and excretion of ^{35}S labeled ester sulfates

The experience gained from this case indicates that it is possible to administer high doses of ^{35}S sulfate without untoward effects through the use of multiple doses Conceivably a considerably higher total dose of ^{35}S sulfate could have been tolerated by the patient and might be utilized in future cases A proposed therapeutic scheme could be week

ly single doses of about 250 mC four times bi monthly until from two to three curies or possibly more had been administered In the execution of such a scheme attention should be given to the hematological response Whenever possible arterial injection or perfusion should be employed rather than intravenous administration Furthermore since the greater portion of a therapeutic dose is eliminated in the urine measures should be taken to reduce undesirable irradiation of the urinary passages particularly the bladder and to ensure complete recovery and safe disposal of the isotope A high urinary output volume should be maintained The use of an indwelling urethral catheter preferably with continuous lavage is also advisable

The possibility of combining ^{35}S treatment with other methods known to depress the synthesis of mesenchymal tissue constituents either by drugs (*Bostrom et al* 1964) or roentgenologic treatment (*Andrews & Holland* 1965) must be further explored It is our opinion that particular attention should be paid to the appropriate timing of such auxiliary measures in relation to the course of ^{35}S sulfate treatment The value of ^{35}S sulfate in the treatment of chondrosarcoma cannot as yet be considered as fully established In our opinion however the present promising observations are a stimulus to further attempts to utilize this radioisotope in the search for an effective non surgical treatment of this malignancy

SUMMARY

A case of chondrosarcoma with pulmonary and skeletal metastases occurring after hemipelvectomy is described in which treatment with ^{35}S-sulfate was successfully applied

The total dose was 1 735 C and is the highest thus far reported The isotope was given in seven separate injections by various intra arterial and intravenous routes during a period of seven months

The patient s general condition improved markedly with the institution of ^{35}S therapy For the last two years he has been leading an essentially normal but sedentary life There has been no increase in the size of the pulmonary metastases Moreover devitalization of the tibial metastasis was obtained as verified histologically

The treatment did not cause any serious damage to the bone marrow Nor were there any signs of damage to other tissues or any symptoms of a generalized radiation sickness Hence a therapeutic scheme involv

ing even higher doses is suggested for future attempts to utilize ^{35}S sulfate in the treatment of chondrosarcoma.

RESUME

On décrit un cas de chondrosarcome avec métastases pulmonaires et osseuses après hemipelvectomie pour lequel un traitement par sulfate de ^{35}S a été appliqué avec succès.

La dose totale a été de 1 735 C et est la plus haute rapportée jusqu'à présent. L'isotope a été administré en 7 injections séparées par diverses voies intraartérielles et intraveineuses pendant une période de 7 mois.

L'état général du patient s'est amélioré de façon notable avec ce traitement.

Au cours des deux dernières années il a mené une vie essentiellement normale mais sédentaire.

Il n'y a pas eu d'accroissement dans la dimension des métastases pulmonaires.

De plus, il a été vérifié histologiquement qu'une dévitalisation des métastases du tibia a été obtenue. Le traitement n'a causé aucun dommage sérieux à moelle osseuse.

Il n'y a pas eu non plus de signes de dommages à d'autres tissus ainsi *que de symptomes de maladie consecutive à une irradiation généralisée.*

Ainsi une thérapie incluant des doses encore plus fortes est suggerée dans les tentatives futures d'utilisation du sulfate dans le traitement de la chondrosarcome.

ZUSAMMENFASSUNG

Eine erfolgreiche Behandlung von pulmonalen und Skelett-Metastasen von Chondrosarcom mit ^{35}S Sulfat nach Hemipelvectomie wird mitgeteilt.

Die totale Dosis war 1 735 C und stellt die höchste bisher publizierte Dosis dar. Die Isotope wurde in 7 separaten Injektionen, teils intravenöse, teils intraarterielle, im Laufe von 7 Monaten verabreicht.

Der Allgemeinzustand des Patienten verbesserte sich während der Behandlung mit ^{35}S Sulfat deutlich. In den letzten beiden Jahren lebte er nahezu normal, jedoch mit begrenzter Aktivität. Es wurde keine Vergrösserung der Lungen-metastasen beobachtet. Ausserdem konnte eine Devitalisierung einer Tibiametastase histologisch nachgewiesen werden.

Die Behandlung hatte keine Schäden des Knochenmarkes zur Folge.

Auch traten keine Zeichen von Gewebsschädigung oder generelle Strahlenschäden in Erscheinung

Auf Grund dessen beabsichtigt man die Dosierung von ^{35}S Sulfat bei zukünftiger Behandlung von Chondrosarcom zu erhöhen

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CONTRACTURE OF THE QUADRICEPS MUSCLE IN CHILDREN

A Report of 12 Cases

By

Rolf Hagen

Received 19 viii 67

The purpose of this paper is to emphasize that an important factor concerning the etiology of quadriceps contracture in children is the administration of intramuscular antibiotic injections into the thighs A total of twelve patients with a flexion deficit in one or both knee joints have been treated during the last four years All the children suffered from severe illnesses soon after birth and received large injections of antibiotics into the thighs Three cases in our material presented several characteristic signs of this disorder and are described here

CASE REPORTS

Case 1 A girl aged one year and six months was born four weeks before term At the age of three weeks she suffered from sepsis originating from the urinary tract and complicated by staphylococcal pneumonia. She received 40 million units of crystalline penicillin into both thighs within a period of six weeks (Figure 1) Two years after the quadriceps-plasty gait and squatting were normal and there was no reduction in strength of the quadriceps muscle (Figure 2) This child is in fact, completely restored

Case 2 A boy aged five years had a congenital ventricular septal defect and was given 130 million units of penicillin because of endocarditis at five months of age A flexion deficit developed in both knees and the condition progressed for two years despite of intense physiotherapy (Figures 3–5) Characteristically during an active or passive attempt to force the flexion the movement was stopped suddenly and exactly at one point as if some mechanical obstacles were in the way The decreased range of flexion was not accompanied by pain and even vigorous efforts to force the hindrance were painless Two years after a bilateral quadriceps plasty



Figure 1



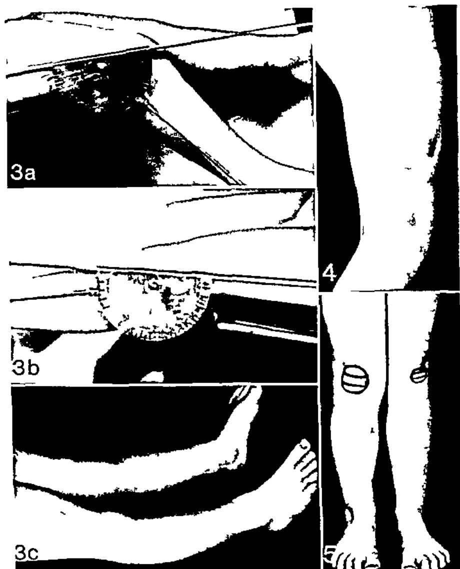
Case 1 Figure 1 Several white puncture marks are shown anterolaterally on the left thigh Similar marks of injections were present on the other thigh Figure 2 40 of flexion before operation Normal range of movement after operation

Figure 2

the gait had improved considerably and he presented a nearly normal squatting ability (Figure 6)

Operation Technique

Figure 7 gives a schematic drawing of the operative procedure The quadriceps muscle was explored through an anterolateral incision The operation consisted of a lengthening of the rectus femoris tendon and iliotibial tract and a simple division of the vastus intermedius tendon and all tight adhesions There was considerable fibrosis in the depth of the subcutaneous tissue the fascia lata was fibrotic and tight it was 4–5 mm thick and was adherent to the underlying muscle The vastus lateralis medialis and intermedius were dissected free from the rectus femoris All four heads of the quadriceps muscle were fibrotic and contracted with massive adhesions to the intermuscular fasciae A Z lengthening of 5 cm of the rectus femoris resulted in some improvement but the further restriction of flexion was caused by tightness of



Figures 3–5

Case 9 Figure 3 Preoperatively 50 of flexion of right knee joint 10 of flexion of the left and 15 of hyperextension on both sides Figure 4 The quadriceps tendon tightened by maximal flexion and the dimples were more visible Figure 5 Left patella hypoplastic and situated higher and more laterally than right

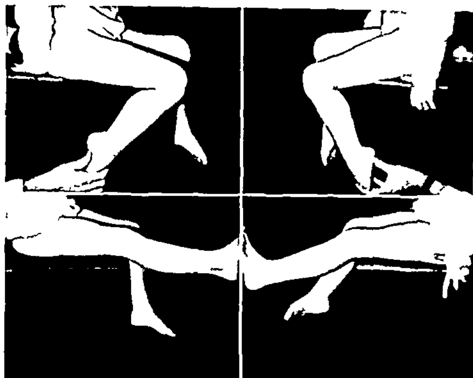


Figure 6

Case 2 Figure 6 Two years after operation knee flexion 10–130° on right side 20–90° on left and passive extension to 0 position on both sides

the vastus intermedius tendon which was divided transversely However full flexion was not possible until the iliotibial tract was lengthened by an oblique incision upward and backward and the insertions of the vastus medialis and lateralis into the central tendon were divided These muscles were sutured to the tendon again while the knee was held in 90° of flexion and a toe to groin cast immobilisation was continued for 2 weeks

Histological Examination

There are considerable degenerative changes in the striated muscle fibres in sections from all parts of the left quadriceps muscle (Figures 8–10) The muscle bundles are partly replaced by fibrous tissue and partly by adipose tissue There is some haemorrhage in the tissue and infiltration with lymphocytes plasma cells and a few granulocytes Conclusively the histological picture is characteristic of muscle tissue

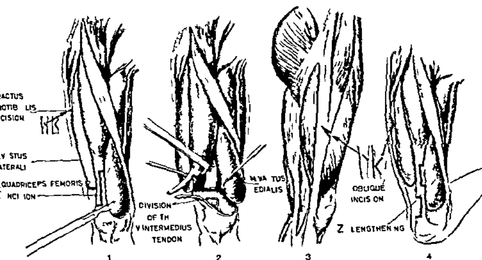


Figure 7

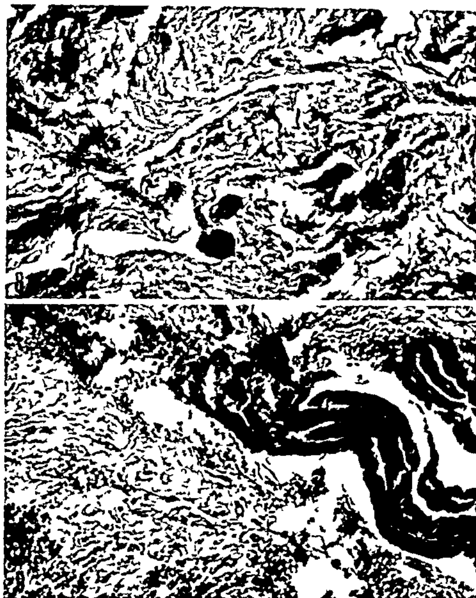
with degenerative changes (Rikshospitalet the Institute of General and Experimental Pathology prof *Olav Hilmar Iversen)*

Case 11 A boy aged 6 years was born six weeks before term and received 14 million units of penicillin from the first day of life because of bronchopneumonia complicated by sepsis The correct diagnosis was established at the age of five years (Figure 11) A modified Smith Petersen incision was employed bilaterally in this case Considerable amounts of fibrotic tissue were removed and the rectus tendon lengthened 4 cm at its origin Postoperatively the patient was put in bed in the prone position with sand bags on the buttocks and with the knees flexed 90 He was out of bed on the 4th postoperative day (Figure 12)

MATERIAL

Table 1 gives details of our twelve patients with quadriceps contracture The material consists of 8 boys and 4 girls There were 1 rightsided 3 leftsided and 8 bilateral contractures Fifty per cent of the children had been born two to eight weeks before term.

Usually the antibiotics had been given because of infections but also as a pro phylactic measure especially in connection with prematurity (case 5 and 7) and operation (case 9) Crystalline penicillin had been given in doses from 8 to 130 million units within a period of 3 to 9 weeks Most of the prematures had received injections from the first day of life case 2 from the age of five months and the remaining were three to four weeks old. Two conservatively treated cases (case 6 and 7) had received antibiotics in small doses All our patients showed evidence of previous thigh injections *i e* puncture marks and dimples.



Figures 8 9

Case 2 Figure 8 Photomicrograph of section of rectus femoris shows that the tissue is replaced by a collagenous and fibrous tissue with comparatively few cells only few preserved muscle bundles Figure 9 Section of vastus medialis shows muscle bundles ending abruptly at a collagenous and fibrous tissue

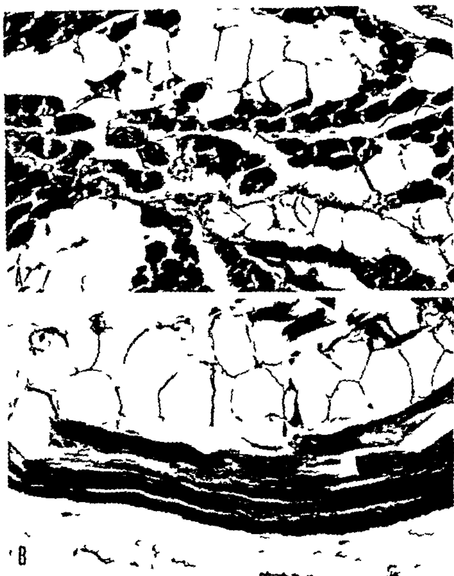


Figure 10 Vastus intermedius (A) and vastus lateralis (B) Individual muscle bundles are partly replaced by adipose tissue

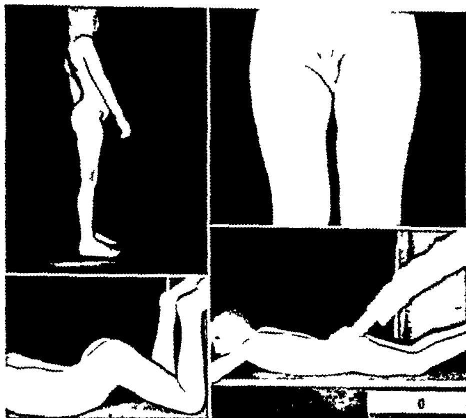


Figure 11

Case 11 Figure 11 Increased lumbar lordosis clearly shown in the prone position with the knee 90 flexed Dimples visible proximally on right thigh With normal lordosis and 0 position in the hip joints only 30 of flexion of the knees

All together 14 operations were performed upon 10 patients, and 4 children had bilateral operations. A flexion of at least 90 is no indication for operative treatment because a knee flexion up to this limit is sufficient for all important movements these cases however are followed up at the out patient department

Table 2 shows the anatomical distribution of fibrosis in 12 operations on 9 patients The operative procedure in these cases was usually the same as that described in connection with case 2

RESULTS

Comparison of the pre and postoperative range of knee movement (Table 1) shows that all cases obtained at least 90 flexion The range of flexion was usually recorded in the prone patient with O position in the hip joints This position may present a lesser degree of flexion

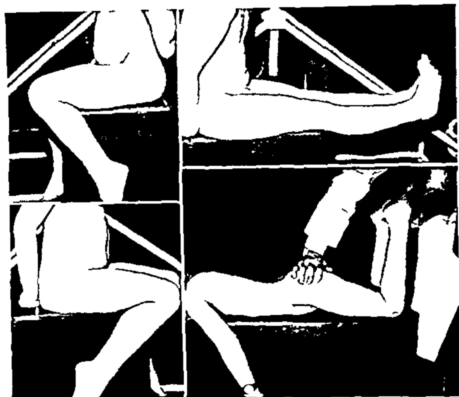


Figure 19

Case 11 Figure 19 One year postoperatively flexion to 130 in sitting position and extension with normal power to 0 in prone position flexion to 90

compared with the sitting position especially if the fibrotic changes and contracture are confined mainly to the rectus femoris Concerning the postoperative active extension the object was to obtain O position by physiotherapy and what is probably more important by stimulating the children as much as possible to daily activity and play Among the patients with a postoperative observation time of 2 years the active extension defect was sometimes 10 20 while there was a little more deficiency of extension among those operated upon during the last 1½ year All these patients have passive extension to O position but no hyperextension The power of the quadriceps muscle continued to improve during the observation period in all the children The quadriceps plasty was modified a little in two cases (case 5 and 8) in order to obtain a stronger extensor mechanism postoperatively The Z

Table 1 Details of twelve patients with quadriceps contracture

Case number	S	Side	Age [illegible]	[illegible]	[illegible] at illness	[illegible]	[illegible]	Degree of preoperative [illegible] R	L	Age at operation	Operation R	L	Time after operation	Degree of postoperative [illegible] R	L
1	F	L	8 mos		Staphylococcal pneumonia Sepsis			Normal	0 40	16 mos			8 yrs	Normal	0 140
2	M	R+L	8 mos		Pyloric stenosis (oper. [illegible]) Subacute [illegible]			0 90	0 10	5 yrs			8 yrs	10 130	20 90
3	F	L	5 mos		Sepsis			Normal	0 90	1 yr			2 yrs	Normal	20 90
4	M	R L	12 mos		Staphylococcal pneumonia Pyopneumothorax			0 120	0 40	3 yrs			3 yrs	0 120	6 90
5	M	R+L	18 mos		P[illegible] [illegible] [illegible]ectasis			0 90	0 30	5 yrs			8 yrs	0 90	0 90
6	M	R L	2 yrs		Pneumonia			0 90	0 90						
7	M	R	3 yrs		[illegible] Icterus neonatorum			0 90	Normal						
8	M	L	3 yr		[illegible] Asphyxia neonatorum			Normal	0 40	2 yrs			18 mos	Normal	0 17
9	F	R+L	5 mos		Esophageal [illegible] (oper. [illegible])			0 70	0 70	4 yrs			18 mos	20 10?	30 9?
10	M	R L	3 yrs		Bronchopneumonia Sepsis			0 30	0 20	4 yr			18 mos	30 90	30 90
	M	R L	5 yrs		Bronchopneumonia Sepsis			0 30	0 30	6 yrs			12 mos	0 90	0 90
12	F	R L	6 y		Sepsis			0 100	0 25	8 yrs			7 mos	0 100	40-95

Table 2 Anatomical distribution of fibrosis in twelve operations on nine patients with quadriceps contracture

MUSCLE AFFECTED	NUMBER OF CASES
VASTUS LATERALIS MEDIALIS INTERMEDIUS AND RECTUS FEMORIS	7
VASTUS LATERALIS INTERMEDIUS AND RECTUS FEMORIS	4
VASTUS LATERALIS AND RECTUS FEMORIS	1

lengthening was performed on the combined tendons of the rectus and vastus intermedius This is perhaps not a sound principle because the rectus is a two-joint muscle and the intermedius a one joint muscle Nevertheless it did not seem to be of any practical significance and at the follow up these two children presented active extension to O position

Preoperatively the younger children had a tendency to keep the lower extremity extended when crawling and were not able to squat while the older children had a peculiar gait and way of running The lower extremity was put forward simultaneously with abduction outward rotation and flexion movement in the hip joint Most of the pa

tients walked with the knee joints nearly extended even though some flexion was still possible They also tended to walk with the legs more or less wide apart especially when walking up hill or upstairs

Locomotion was much better after the operation not only for unilateral but also for bilateral contracture The abduction and outward rotation movements disappeared completely The knee stability seemed to be satisfactory because the hamstrings support the extensor muscles in this respect

ETIOLOGY

Similar reports on quadriceps contracture in children have been published in the last 6 years and it appears that *J V Todd* (11) was the first to mention this subject and to warn against injections

Steen Johnsen (10) has reported one case in a paper on intramuscular injections and recommended treatment with exercises because the flexion deficit was moderate in his patient

Hnevkovsky (6) published 12 cases and has later collected a total of 17 cases (*Lloyd Roberts & Thomas* 1964) But he was able to establish a definite history of injections into the thigh in only 4 of them He emphasized that there may be two syndromes the progressive idiopathic type due to a congenital muscular dysplasia of rectus and intermedius and the type due to injections

Fairbank & Barrett (1) described identical girl twins with flexion deficits in both knee joints They assumed a genetic origin and thought the contracture to have most in common with congenital torticollis In 1964 however *Lloyd Roberts & Thomas* reported that the twins had been given intramuscular antibiotics for a month because of prematurity but the exact site of these injections is not known Their own material of 6 patients had all received injections into the thighs (8)

Gammie Taylor & Urich (2) suggested that the condition might be due to a congenital muscle contracture related to that occurring in club foot or Sprengel s shoulder

Gunn (3) reported 22 cases from Singapore 15 of which were due to injections At the same time *Karlen* published 6 cases also from Singapore He was in agreement with *Hnevkovsky* and used the term congenital fibrosis of the vastus intermedius for his cases

Lastly *Saunders Hoefnagel & Staples* (9) presented one case with a unilateral contracture due to injections

DISCUSSION

The appearance of these contractures during the last 10 years may be related to the increasing frequency of antibiotic injections into the quadriceps muscle. However, detailed clinical histories are not always given. It is therefore not known how many children in these materials were premature or had illnesses that might have required intramuscular injections. Six cases in our material presented illustrative diagnostic problems and the evidence of previous injections could be very difficult to observe and was indeed overlooked by several physicians. Case 2 was interpreted as either arthrogryposis or a rare neurological disease. Case 3 was first thought to be due to trauma, then to inflammation and thirdly to a discoid meniscus, and in addition a postpoliomyelitic paresis due to the atrophy, shortening of the inferior extremity and an absent patellar reflex. Case 4 and 5 were erroneously diagnosed as being snapping hip and Calvé-Legg-Perthes disease. Lastly, in case 6 the gait led to the diagnosis of cerebral palsy and it appeared to be difficult to demonstrate the clinical history because the child had been adopted in early infancy and the puncture marks could only be seen under a magnifying glass.

Summarizing the analysis of our material and similar reported cases seem to indicate that most of these contractures are due to injections but still a few cases may be of a congenital origin.

Concerning the pathogenesis in our cases, the most reasonable explanation seems to be that the injections induce considerable oedema and haemorrhage and even necrosis in the muscle with the subsequent development of fibrosis, adhesions and contractures. It is very likely that the injected amount of antibiotic is too large in relationship to the volume of the muscle and in this way separates the muscle bundles and fibres. Another important factor may be that the blood flow of the muscle is dependent upon the activity of the latter and probably only a minor portion of the capillaries are active in these quietly lying severely ill newborn children. Consequently the resorption continues during a much longer period of time and the quadriceps muscle is saturated with the injected antibiotic solution (4). Nurses who attended some of these children were often astonished by the swelling of the thigh following these large and repeated injections and for several weeks case 2 presented even a necrosis in the left thigh. *Harrold* (5) has described a similar pathogenetic condition of rigid valgus foot from

fibrous contracture of the peronei probably due to pressure from a splint leading to muscle ischemia and death

Most of our patients received smaller doses of streptomycin and chloromycetin in addition to penicillin However it is supposed to be of less importance what kind of antibiotic is injected even if a difference in their tissue damaging effect could be due to various properties of the solutions *i e* an unphysiological pH hypertonicity or a direct myotoxic effect (4) The severity of the symptoms is dependent upon the amount of antibiotics injected the duration of the treatment and the interval between such treatment and surgical intervention

The pediatricians play an important role regarding prophylactic measures of this disorder (4) It is very important to keep children with a history of previous injections under observation in order to ob tain an early diagnosis of progressive flexion deficits From the ex ample of our first patient it appears that the prognosis seems to be very *good if the condition is recognized in early infancy*

SUMMARY

A *material* of twelve cases of quadriceps contracture in *children* is analysed with special reference to the clinical and microscopical pic tures All the children had severe illnesses soon after birth and received large injections of antibiotics into the thighs It is assumed that the injections induce oedema haemorrhage and even necrosis in the qua driceps muscle with the later development of fibrosis and contracture

Lengthening of the rectus femoris and the iliotibial tract and divi sion of the vastus intermedius tendon and all tight adhesions proved to be successful and restored good function

RESUME

Un materiel d observation de 12 cas de contracture du quadriceps chez des enfants est analyse et il est donne une description du tableau clini que et microscopique Tous les enfants avaient souffert de maladies graves peu de temps *après la naissance et avaient reçu des injections* d antibiotiques dans la cuisse Il est suppose que les injections ont provoque de l oedeme des hemorragies et peut etre meme des necroses dans le muscle quadriceps avec plus tard la formation de fibrose et de contracture

La longueur du droit antérieur femoral et de la region iliotibiale

ainsi que la division du tendon vaste interne et toutes les insertions de la cuisse semblent être excellentes avec une bonne restauration fonctionelle

ZUSAMMENFASSUNG

Ein Material von zwölf Fällen von kindlichen Quadricepskontrakturen mit besonderer Beschreibung des klinischen und histologischen Bildes wird analysiert Alle Kinder litten an schweren Erkrankungen kurz nach der Geburt und erhielten grosse Injektionen von Antibiotica in die Oberschenkel Man nimmt an dass die Injektionen Ödem Blutungen und sogar Nekrosen im Quadricepsmuskel hervorriefen die später zur Entwicklung von Fibrose und Kontraktur führten Verlängerung des Rectus femoris und Tractus ileotibialis sowie Überschneidung der Sehne des Vastus intermedius und aller straffen Verwachsungen erwiesen sich als erfolgreich und stellten eine gute Funktion wieder her

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Acta orthop Scandinav 39 579–59? 1968

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(Head Professor Eivind Thomasen M D)

MUSCLE RECOVERY IN POLIOMYELITIS

By

Niels Bukh

Received 7 i 67

...letely or partly paralysed muscles ... power during the first years after ... iously been performed by *Lovett* ...55) *Sharrard* (1955) and others ... up through 5½ years of patients ... demics primarily in the Hospital ...org and in the Orthopaedic Hospi... ...d and Funen ...d by the National Health Service ...of 3134 paralytic cases 2060 in the ...pidemic Out of these 3134 para... ...in Jutland or Funen In this area ...emaining 1032 paralytic cases 508 ... the named hospitals Out of these ...0 females 155 were over 15 years ... under 4 years The age distribution ...ed patients in the whole of Den... ... and 70 per cent children under 15

...le recovery as reliable as possible ...e 508 These were partly patients ... out within 3 months of the onset ...n over 4 years of age The group ...23 children in the age range 4–15

... through ... these 240 cases by regular tests ... were based upon 6 tests done

(1) an average of 6 weeks after the onset of poliomyelitis
(2) „ „ „ 3 months „ „ „ „
(3) „ 6 months „ „ „
(4) „ 1 year „ „ „
(5) „ 2 years „ „ „ „
(6) 5½ years „ „ „

The evaluation was done by manual testing of the power of each individual muscle in a systematic test of the most important muscles All the tests were performed by the same two examiners (N B and E T) In assessing muscle power the grading suggested by *Lovett* was used

0 = No contraction
1 = Trace of contraction
2 = Active movement with gravity eliminated
3 = Active movement against gravity
4 = Active movement against gravity and some resistance
5 = Normal power

Muscles having grade 3 power or over were listed as muscles of functional value

At the first test done an average of 6 weeks after the onset of polio the following results were recorded

	919	grade 0	muscles
	1483	„ 1	
	1643	„ 2	
	2079	3	„
	2006	4	„
Total	8080	muscles	

If the improvement in muscle power during the 5½ years of the follow up is taken to be 100 about 50 per cent of the improvement occurred within the first 6 months after the onset of polio about 75 per cent within the first year and 90-95 per cent within the first 2 years The findings for grade 0 muscles were somewhat different the improvement in these muscles within the first 6 months being 70 per cent and within the first year almost 90 per cent (Figure 1)

Skinhoj found that of 702 grade 0 muscles in his study 70 per cent were still grade 0 at follow up 3 years later and that only 12 per cent were of functional value

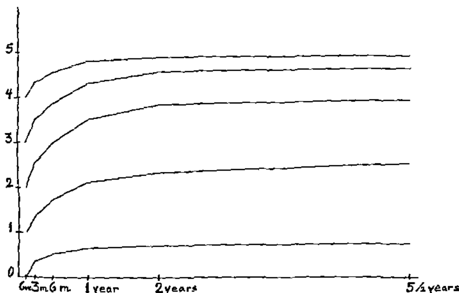


Figure 1 Muscle recovery through 5½ years for all muscles of grade 0 1 2 3 and 4 from all 940 patients

In the present material 80 per cent of 919 grade 0 muscles remained grade 0 or 1 at the end of 5½ years while 10 per cent had attained functional value

Out of the 682 muscles which were still grade 0 three months after the onset of polio 95 per cent remained grade 0 or 1 at the end of 5½ years and only 2 5 per cent were of functional value

Correspondingly of the 600 grade 0 muscles at 6 months 97 per cent still remained grade 0 or 1 at the end of 5½ years and only ½ per cent had attained functional value

In other words a muscle which remains grade 0 three months after the onset of polio has a very poor prognosis

The prospects for grade 1 and 2 muscles in the present material were as follows

Of 1483 grade 1 muscles 50 per cent had gained functional value at the end of 5½ years

Of 1643 grade 2 muscles 88 per cent had gained functional value at the end of 5½ years

Sharrard reported that of 575 grade 1 and 2 muscles 56 per cent were of functional value at the end of 3 years

A *comparison of muscle recovery in children and adults showed*

5
4
3
2
1
0
6w 3m 6m 1 year 2 years 5½ years

Figure 2 Muscle recovery through 5½ years for all muscles of grade 0, 1, 2, 3 and 4 In patients over 15 years of age solid line In patients aged 5–15 years dotted line

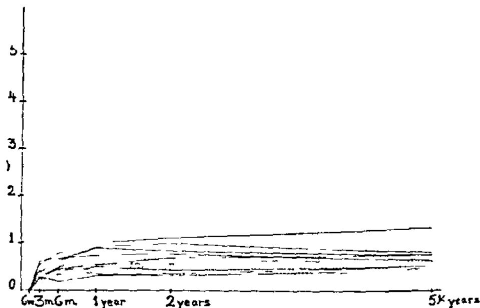


Figure 3 Muscle recovery through 5½ years for all grade 0 muscles in the lower limbs Muscles above the knee solid line Muscles below the knee dotted line

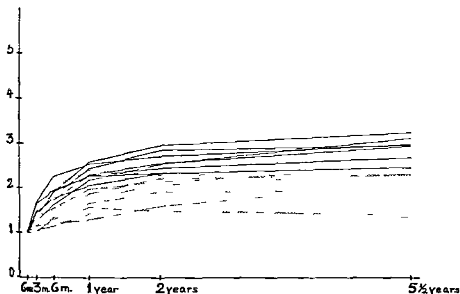


Figure 4 Muscle recovery through 5½ years for all grade 1 muscles in the lower limbs Muscles above the knee solid line Muscles below the knee dotted line

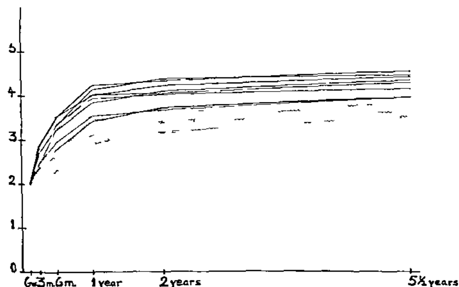


Figure 5 Muscle recovery through 5½ years for all grade 2 muscles in the lower limbs Muscles above the knee solid line Muscles below the knee dotted line

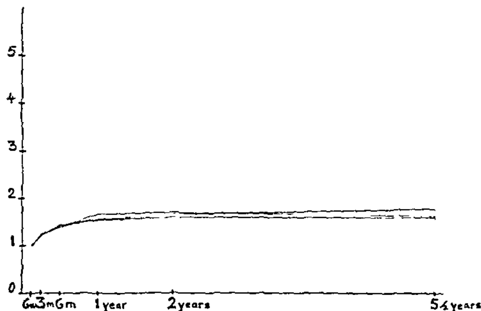


Figure 6 Muscle recovery through 5¼ years for all grade 1 abdominal muscles solid line and all grade 1 back muscles dotted line

0
1
2
3
4
5
6w 3m 6m
1 year
2 years
5½ years

Figure 7 Muscle recovery through 5½ years for all grade 2 abdominal muscles solid line and all grade 2 back muscles dotted line

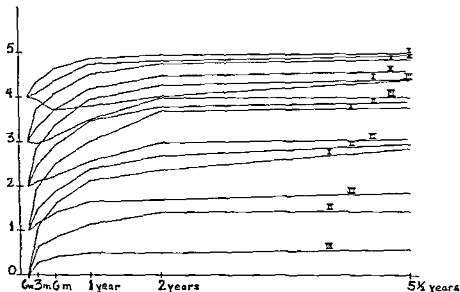


Figure 8 Muscle recovery through 5¼ years for all grade 0 1 2 3 and 4 muscles from all 240 patients divided into three sub-groups according to their site i e in limbs having degree I II or III total paralysis

hardly any definite difference in the present material (Figure 2) A finding of better regeneration in children by previous workers may be due to the inclusion of children under 4 years of age in whom the assessment of muscle function must be fairly uncertain

In respect to the ability of the individual muscles to recover the proximal groups of muscles in the lower limbs seemed to have a some what better prognosis than the peripheral ones This is in keeping with previous findings (Figures 3 4 and 5) In the upper limbs it has *not* been possible to demonstrate any definite difference between proximal and peripheral muscles apart from the poor outlook for the opponens pollicis The prognosis for abdominal muscles was poor *for back* muscles fairly good (Figures 6 and 7) *Skinhoj's* material showed the same findings for the opponens and abdominal muscles

A factor which appears to be of decisive importance to the prognosis of the individual muscle is the degree of paralysis in adjacent muscles i e the total functional defect in the limb In the event of severe para lysis of two or more functionally important muscles we classified the degree of paralysis in the limb as III i e a severe functional loss *in the* limb concerned In these cases there are invariably severe widespread

paralyses With a functional defect of moderate degree the limb was listed as having a degree II paralysis and with slight functional reduction it was listed as degree I

Table 1

Muscle power	Time of test	Difference found in the course of the curves showing muscle recovery for all grade 0 1 2 3 and 4 muscles in limbs having		
		I–II paralysis	I–III paralysis	II III paralysis
0	3 months	significant	significant	significant
	6 months		"	"
	1 year		"	"
	2 years		"	"
1	3 months	significant	significant	significant
	6 months		"	"
	1 year			"
	2 years		"	"
2	3 months	significant	significant	significant
	6 months	"		"
	1 year		"	"
	2 years			"
3	3 months	significant	significant	significant
	6 months		"	"
	1 year			"
	2 years	"		"
4	3 months	significant	significant	not significant
	6 months		"	" "
	1 year	"	"	" "
	2 years	"		" "

If the muscles found at the first test to be of the same degree of paralysis are divided into 3 sub groups according to their site—*i e* in a limb with degree I II or III total paralysis—they show a decisive difference in their tendency to recover Muscles in a severely paralysed limb show very little improvement On the other hand muscles in a slightly paralysed limb have a very favourable prognosis (Figure 5) This factor is of such decisive importance that even long lasting systematic training does not essentially alter the course this seems important in deciding how long a systematic training should reasonably be continued The difference between the prognosis for muscles in

Table 2 Frequency of affection of lower limb muscles
Muscles listed according to frequency of involvement

Sharrard (142 patients)		Present material (240 patients)	
Quadriceps	184	Tibialis anterior	200
Gluteus medius	178	Gluteus medius	184
Internal popliteal	168	Iliopsoas	183
Biceps femoris	164	Tibialis posterior	176
Adductors	162	Biceps femoris	174
Iliopsoas	159	Tensor fasciae latae	171
Tibialis anterior	152	Adductors	164
Tensor fasciae latae	149	Quadriceps	162
Gluteus maximus	142	Internal popliteal	153
Tibialis posterior	140	Extensor digitorum longus	142
Flexor hallucis longus	133	Gluteus maximus	132
Flexor digitorum longus	130	Extensor hallucis longus	128
Extensor digitorum longus	130	Triceps surae	120
Triceps surae	129	Peronei	109
Peronei	126	Flexor hallucis longus	106
Extensor hallucis longus	125	Flexor digitorum longus	100

Table 3 Incidence of complete and partial paralysis of lower limb muscles (after Sharrard 1955) Muscles listed according to frequency of complete paralysis Ratio partial to complete paralysis Approximate length of motor cell column in the cord

	Number completely paralysed	Number partially paralysed	Ratio partial to complete paralysis	Approximate length of motor cell column in the cord
Tibialis anterior	103	49	0 47	8 mm
Tibialis posterior	89	51	0 57	8 mm
Flexor digitorum longus	85	45	0 52	8 mm
Flexor hallucis longus	84	49	0 58	8 mm
Extensor hallucis longus	66	59	0 89	9 mm
Extensor digitorum longus	63	67	1 06	10 mm
Peronei	60	66	1 10	10 mm
Triceps surae	57	72	1 26	14 mm
Biceps femoris	54	110	2 03	14 mm
Gluteus medius	47	131	2 78	16 mm
Quadriceps	46	138	3 00	22 mm
Internal popliteal	43	1[illegible]5	2 90	20 mm
Tensor fasciae latae	38	111	2 9[illegible]	16 mm
Adductors	36	1[illegible]	3 50	22 mm
Iliopsoas	34	1[illegible]5	3 67	23 mm
Gluteus maximus	33	109	3.30	17 mm

limbs with I II and III paralysis proved with a single exception to be statistically significant (Table 1[1])

Several workers int al *Lovett, Skinhoj* and *Sharrard*, have found that while the absolute number of affected muscles was greater for the proximal than for the distal lower limb muscles (Table 2) the number of completely paralysed muscles was greater in the lower leg and foot On this basis *Sharrard* calculated a coefficient partial/complete paralysis for each muscle in the lower limbs and found this coefficient to be lowest in the distal muscles A similar analysis of our material showed a certain agreement (Tables 3 and 4) The great difference in the level of coefficients in *Sharrard's* material and ours is probably due to a difference in the severity of the epidemics and perhaps also to a difference in patient selection

Table 4 Present material listed in the same way as Sharrard's (Table 3)

	Number completely paralysed	Number partially paralysed	Ratio partial to complete paralysis	Approximate length of motor cell column in the cord
Tibialis anterior	91	109	1.20	8 mm
Tibialis posterior	52	124	2.38	8 mm
Extensor hallucis	41	87	2.12	9 mm
Peronei	40	69	1.72	10 mm
Quadriceps	38	124	3.26	22 mm
Extensor digitorum longus	37	103	2.80	10 mm
Internal popliteal	28	125	4.46	20 mm
Adductors	29	136	4.69	22 mm
Iliopsoas	27	156	5.77	23 mm
Biceps	26	148	5.69	14 mm
Flexor hallucis longus	25	81	3.24	8 mm
Flexor digitorum longus	23	77	3.35	8 mm
Triceps surae	23	97	4.22	14 mm
Gluteus medius	16	168	10.50	16 mm
Gluteus maximus	15	117	7.80	17 mm
Tensor fasciae latae	12	159	13.25	16 mm

In the same way *Sharrard* found that the average number of completely or partly paralysed muscles supplied by a given spinal segment was largest for the L 1 L 2 and L 3 segments falling below this level

[1] Calculated by *Erling Dessau*

while the average number of completely paralysed muscles supplied by a given segment was almost the same from L 4 downwards About the same applies to our material (Table 5)

Table 5 Average number of partially or completely (2nd column) and completely (3rd column) paralysed muscles innervated from each cord segment
Present material

	Average number of partially or completely paralysed muscles	Average number of completely paralysed muscles
L 1	183	27
L 2	169	31
L 3	169	31
L 4	177	38
L 5	149	34
S 1	143	35
S 2	137	31

Similarly *Sharrard* in his very interesting pathological studies on the spinal cords from 7 polio patients found a characteristic difference in the length of the columns of anterior horn cells which form the nerve nuclei of the individual muscles He demonstrated that while the proximal muscles in the hip region and in the thigh are supplied by relatively long cell columns the cell columns for the muscles on the lower leg and foot are considerably shorter This he took to explain the previously mentioned fact that the total number of completely or partly paralysed muscles is greater for the proximal muscles while the number of completely paralysed muscles is larger as far as the distal muscles are concerned (Tables 3 and 4)

SUMMARY

Muscle recovery through 5½ years after the onset of poliomyelitis was assessed by regular testing of muscle power in 240 patients 117 adults and 123 children over 4 years of age The assessment was based upon manual testing of muscle power 6 weeks 3 6 and 12 months 2 and 5½ years after the onset of polio It was found that about 50 per cent of muscle recovery took place within the first 6 months a total of about 75 per cent within the first year and a total of 90–95 per cent within the first 2 years As far as grade 0 muscles were concerned however

these findings were 70 per cent, 90 per cent and 95 per cent respectively A finding of great importance was that muscles which we grade 0 three months after the onset of polio had a very poor prognos 95 per cent remaining grade 0 or 1 As far as the grade 1 or 2 muscl were concerned 50 per cent and 88 per cent acquired functional val in 5½ years

In this material there did not seem to be any definite difference b tween muscle recovery in adults and children

The prognosis seems somewhat better for proximal than for dis muscles in the lower limbs poor for the opponens pollicis and pc for the abdominal muscles

A certain conformity was found on comparison with *Sl inhoj s* a with *Sharrard s* findings For instance the absolute number of co pletely or partly paralysed muscles was found to be largest for t *proximal lower limb muscles while the largest number of totally pa* lysed muscles was found in the lower leg and foot

The ability for recovery in a muscle of any paralytic grade depen largely upon the degree of total paralysis *i e* the functional defect the limb concerned If the total defect is severe the prognosis is po If it is mild the prognosis is favourable

RESUME

La guérison des muscles a été étudiée pendant 5 ans et demi après u attaque de poliomyélite par le test de la force musculaire chez 2 malades 117 adultes et 123 enfants de plus de 4 ans L observation base sur le test manuel de la force des muscles 6 semaines 3 6 et mois 2 et 5 ans ½ après l attaque de polio Il a été constaté que po environ 50 pour cent des cas la guérison des muscles a lieu dans premiers six mois pour environ 75 pour cent durant la première ann et pour un total de 90 à 95 pour cent durant les deux premières ann *En ce qui concerne les muscles classés 0 ces données sont cependant* 70 pour cent 90 pour cent et 95 pour cent respectivement Une tr vaille de grande importance est que les muscles classés 0 trois m après l attaque de polio ont un pronostic très défavorable 95 pour ce restent au degré 0 ou 1 En ce qui concerne les muscles de degré 1 ou 50 pour cent et 88 pour cent acquirerent une valeur fonctionelle da l espace de 5 ans et demi

Dans ce materiel d observation il ne semble pas exister de differer nette entre la guérison des muscles chez les adultes et les enfants

Le pronostic semble etre un peu meilleur pour les muscles de la rtie proximale des extremites inferieures que pour ceux de la partie stale il est mauvais pour l opposant du pouce et pour les muscles dominaux

Il a ete trouve une certaine conformite en effectuant une comparai n avec les trouvailles de *Skinhoj* et de *Sharrard* C est ainsi que le mbre absolu des muscles antierement ou partiellement paralyses est plus eleve pour les muscles de la partie proximale des extremites ferieures alors que c est dans la partie inferieure de la jambe et dans pied qu on a trouve le plus grand nombre de muscles totalement ralyses

La faculte de guerison d un muscle depend largement du degre de la ralysie générale ou de la defectuosite fonctionnelle du membre dont s agit Le pronostic est defavorable si l etat general est mauvais alors ie le pronostic est favorable si l etat general n est que legerement fectueux

ZUSAMMENFASSUNG

uskelerholung wahrend 5½ Jahren nach dem Beginn von Polio yelitis wurde mittels regelmässiger Prüfung der Muskelkraft bei 240 atienten 117 Erwachsenen und 123 Kindern uber 4 Jahre festgestellt ie Schatzung hatte zur Grundlage die manuelle Prufung der Muskel raft 6 Wochen 3 6 und 12 Monate 2 und 5½ Jahre nach dem Beginn er Poliomyelitis Es wurde gefunden dass ungefahr 50 Prozent der uskelwiederherstellung während der ersten 6 Monate stattfindet ein esamtwert von ungefahr 75 Prozent innerhalb des ersten Jahres und n Gesamtbetrag von 90–95 Prozent innerhalb der ersten 2 Jahre Inso rn als es die Grad 0 Muskeln betraf waren diese Befunde jedoch 70 rozent 90 Prozent und 95 Prozent beziehungsweise Ein Befund von rosser Wichtigkeit war dass Muskeln die drei Monate nach dem Be nn der Polio Grad 0 waren eine sehr schlechte Prognose hatten in m 95 Prozent Grad 0 oder 1 verblieben So weit es sich um Grad 1 nd 2 Muskeln handelte erwarben 50 Prozent und 88 Prozent einen nktionellen Wert im Verlaufe von 5½ Jahren

In diesem Materiale schien kein sicherer Unterschied zwischen der uskelerholung von Erwachsenen und Kindern zu bestehen

Die Prognose scheint etwas besser fur die proximalen als für distalen uskeln der unteren Extremitet zu sein schlecht fur den Opponens ollicis und die Bauchmuskeln

Eine gewisse Übereinstimmung mit den Befunden von Skinhoj und Sharrard wurde gefunden. Zum Beispiel die absolute Zahl von vollständig oder teilweise gelähmten Muskeln wurde am grössten für die proximalen Muskeln der unteren Gliedmasse gefunden, während die grösste Anzahl von vollständig gelähmten Muskeln im Unterschenkel und Fuss gefunden wurde.

Die Erholungsfähigkeit eines Muskels von irgendeinem Lähmungsgrad hängt weitaus von dem Grade der totalen Lähmung ab, d.h. von dem funktionellen Defekt der betroffenen Gliedmasse. Wenn der totale Defekt schwer ist, wird die Prognose schlecht sein, ist er mild, dann ist die Prognose günstig.

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